GE Healthcare

Affinity

Reference Guide for BIOMEDICAL TECHNICIANS

2010 Edition

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Affinity

Reference Guide for

BIOMEDICAL TECHNICIANS

2010 Edition

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Dedication

This book is dedicated to the many biomedical equipment technicians who have devoted countless hours of personal time in advancing the profession of biomedical equipment technology. We would also like to acknowledge appreciation to our families for their time and understanding.

Acknowledgement

We would like to acknowledge our appreciation to the authors and publishers of the texts used as references in writing this book. Without their efforts the publication of this book would not have been possible. In addition we would like to acknowledge the contributions of Penn State New Kensington for its support of first edition of this text.

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Preface

The 2010 Edition of the Affinity Biomedical Reference Guide for Biomedical Technicians is an updated version originally published by Leslie R. Atles and Scott Segalewitz. It is a compilation of information we believe to be beneficial to individuals in biomedical technology. We strived to focus on technologic areas we felt most useful. This book is an attempt to cover a broad range of frequently sought after information. Our objective was not to aspire to address all areas of biomedical technology with this publication, nor was it intended as a replacement for information in existing textbooks.

Please refer to the reference sources used for complete information on any subject covered in this text. All information used in this text is referenced and believed to be accurate at the time of this printing. Readers should always verify codes and standards with their local governing agencies.

The underwriting of the 2010 Edition of this book by GE Healthcare was directed at providing biomedical equipment technicians access to information to assist them in their daily jobs, continuing education and Certification exams.

2010 Editors

Philip Camillocci
Brian Schuster

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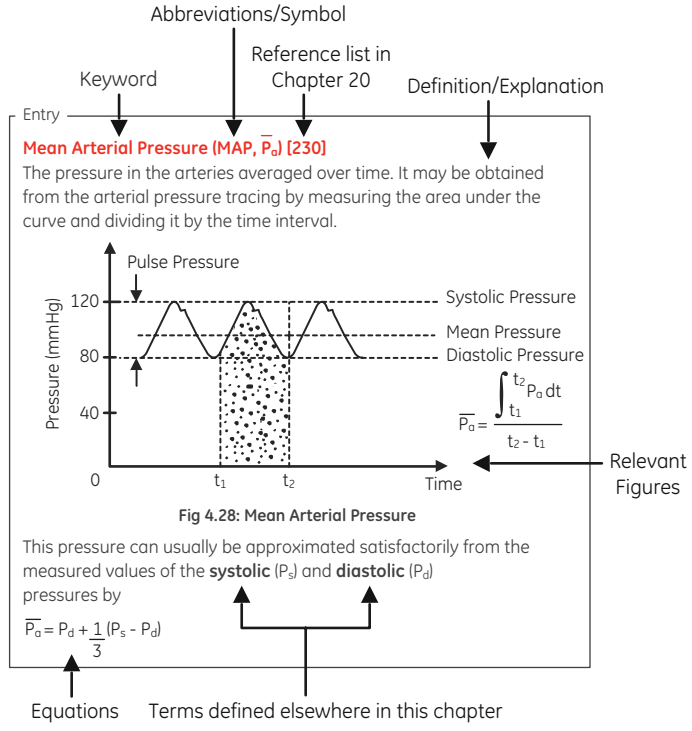
How to Use This Book

This book has been designed to be used as a reference source book. Knowledge on topics can vary depending on authors and/or agencies generating information. For this reason, the book has been designed to identify sources' by placing a reference source number with each comment or entry. In the back of this book is a bibliography that corresponds to the numbering used throughout the text.


Abbreviations/Symbol
Reference list in Chapter 20
Keyword
Definition/Explanation
Entry
Mean Arterial Pressure (MAP, $\overline{P_a}$) [230]
The pressure in the arteries averaged over time. It may be obtained from the arterial pressure tracing by measuring the area under the curve and dividing it by the time interval.
Pulse Pressure
Pressure (mmHg)
120
80
40
0
t_1
t_2
Time
Systolic Pressure
Mean Pressure
Diastolic Pressure
$\overline{P_a} = \frac{\int_{t_1}^{t_2} P_a\,dt}{t_2 - t_1}$
Relevant Figures
Fig 4.28: Mean Arterial Pressure
This pressure can usually be approximated satisfactorily from the measured values of the **systolic** (P_s) and **diastolic** (P_d) pressures by
$\overline{P_a} = P_d + \frac{1}{3}(P_s - P_d)$
Equations
Terms defined elsewhere in this chapter

01
Electrical Safety, Codes, and Standards

1 – Electrical Safety, Codes, and Standards

AAMI Standard Test Load [108]

Using the AAMI standard test load and a volt meter calibrated to indicate rms millivolts, the weighted risk current is read directly from the meter, because:

$$I\ (\mu A\ rms) = \frac{V\ (m\ V\ rms)}{Z\ (k\ \ ohms)}$$

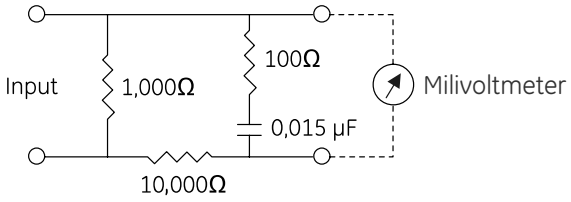


Fig 1.1 – AAMI Standard Test Load

The test load shall be constructed using metal-film resistors with a tolerance of 1 percent or better and a mica- or plastic-dielectric (extended foil) capacitor with a tolerance of 5 percent or better.

Alternate Power Source [110]

One or more generator sets, or battery systems where permitted, intended to provide power during the interruption of the normal electrical service; or the public utility electrical service intended to provide power during interruption of service normally provided by the generating facilities on the premises.

Anesthesia Location [110]

Any area of the facility that has been designated to be used for the administration of any flammable or nonflammable inhalation anesthetic agents in the course of examination or treatment, including the use of such agents for relative analgesia.

Appliance [110]

Electrical equipment, generally other than industrial, normally built in standardized sizes or types, is installed or connected as a unit to perform one or more functions.

Area of Administration [110]

Any point within a room within 15 ft (4.3m) of oxygen equipment, or any enclosure containing or intended to contain an oxygen-enriched atmosphere.

Atmosphere [110]

The pressure exerted by, or any gaseous composition of, an environment. As employed in this standard, atmosphere may refer to the environment within or outside a hyperbaric facility. When used as a measure of pressure, atmosphere is expressed as a fraction of the standard air pressure [14.7 psi (101.4 kPa)].

Branch Circuit [110]

The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s). Conforms to NFPA 70, National Electric Code.

Bulk Systems (Bulk Nitrous Oxide System) [110]

An assembly of equipment as described in the definition of a bulk oxygen system that has a storage capacity of more than 3,200 lb (1,452 kg) [approximately 28,000 cu ft (793 m^3) (NTP) of nitrous oxide (MGS).

Bulk Systems (Bulk Oxygen System) [110]

An assembly of equipment such as oxygen storage containers, pressure regulators, pressure relief devices, vaporizers, manifolds, and interconnecting piping that has a storage capacity of more than 20,000 cu ft (566 m^3) of oxygen (NTP) including unconnected reserves on hand at the site. The bulk oxygen system terminates at the point where oxygen at service pressure first enters the supply line. Note: The oxygen containers may be stationary or movable, and the oxygen may be stored as gas or liquid (MSG).

Clinic [110]
A health care facility where patients are seen on an ambulatory basis, but where surgery involving general anesthesia is not performed.

Combustible [110]
A substance that if ignited will react with oxygen and burn.

Conductive [110]
Not only those materials, such as metals, that are commonly considered electrically conductive, but also that class of materials that, when tested in accordance with this document, have a resistance not exceeding 1,000,000 Ω. Such materials are required where electrostatic interconnection is necessary.

Critical Branch [110]
A subsystem of the emergency system consisting of feeders and branch circuits supplying energy to task illumination, special power circuits, and selected receptacles, serving areas and functions related to patient care, that can be connected to alternate power sources by one or more transfer switches during interruption of normal power sources.

Critical Equipment [110]
The equipment essential to the safety of the occupants of the facility.

Critical Systems [110]
A system of feeders and branch circuits in nursing homes and custodial care facilities arranged for connection to the alternate power source to restore service to certain critical receptacles, task illumination, and equipment.

Cylinder [110]
A supply tank containing high-pressure gases or gas mixtures at pressures that may be in excess of 2,000 psig (13.8 kPa gauge).

Direct Electrical Pathway to the Heart [110]
An externalized conductive pathway, insulated except at its ends, one end which is in direct contact with the heart muscle and the other outside the body, and is accessible for inadvertent or intentional contact with grounded objects or energized, ground-referenced sources. Electrodes, such as may be used for pacing the heart, and catheters filled with conductive fluids are examples of direct electrical pathways to the heart.

Double-Insulated Appliances [110]
Appliances having an insulation system comprising both basic insulation necessary for the functioning of the appliance and for basic protection against electric shock and supplementary insulation. The supplementary insulation is independent insulation provided in addition to the basic insulation to ensure protection against electric shock in case of failure of the basic insulation.

Electrical Life Support Equipment [110]
Electrically powered equipment whose continuous operation is necessary to maintain a patient's life.

Electrode [110]
An electrically conductive connection to a patient. Some electrodes of interest are:

- **Active Electrode:** An electrode intended to generate a surgical effect at its point of application to the patient.
- **Bipolar Electrode:** An electrode consisting of adjacent contacts (e.g. the two legs of a forceps) such that the high frequency current passes between the pair of contacts generating the surgical effect.
- **Dispersive Electrode:** An electrode intended to complete the electrical path between patient and appliance and at which no surgical effect is intended. It is often called the "indifferent electrode," the "return electrode," the "patient plate," or the "neutral electrode."

Classification of Electromedical Apparatus [108 ES1]
For the purpose of this standard, four categories of electromedical apparatus have been defined. In each case, risk current limits are established for the patient connection (if applicable), the cord-connected grounding conductor or exposed electrically conductive surface, and the permanently connected grounding conductor or exposed electrically conductive surface. These four categories are described below.

Electromedical Apparatus [108 ES]
Any instrument, equipment, system, or device that directly or indirectly uses electricity for any medical purpose. Also included are parts that are connected to such equipment and that are required for the normal use of the equipment, including the associated patient wiring or cables.

Electromedical Apparatus with Isolated Patient Connection [108 ES]
Electromedical apparatus intended to be connected to the patient circuit that is isolated from ground, utility power systems, and other supporting circuitry to such a degree that the risk current at the patient connection(s) meets the limits set in this standard for isolated patient connections.

Electromedical Apparatus with Non-isolated Patient Connection [108 ES]
Electromedical apparatus intended to be connected to the patient and for which the risk current at the patient connection(s) meets the limits set in this standard for non-isolated patient connections.

Electromedical Apparatus Likely to Contact the Patient [108 ES]
Electromedical apparatus that does not have a patient connection, but which is intended for use in the patient vicinity.

Electromedical Apparatus with No Patient Contact [108]
Electromedical apparatus that is intended for use outside the patient's vicinity and has no patient connection.

Emergency System [110]
A system of circuits and equipment intended to supply alternate power to a limited number of prescribed functions vital to the protection of life and safety, with automatic restoration of electrical power within 10 seconds of power interruption.

Exposed Electrically Conductive Surfaces [108 ES1]
Any external metal or otherwise electrically conductive surface, which is connected to the internal circuits, mechanisms, or chassis.

Fault Current [108 ES1]
A current in an accidental connection between an energized and a grounded or other conducting element, resulting from a failure of insulation, spacing, or containment of conductors.

Isolated Patient Connection [108 ES1]
A connection between the patient and the electromedical apparatus that is isolated from ground, the utility power system, and other supporting circuitry to such a degree that the risk current flowing through the connection does not exceed the limits for isolated patient connection specified by standards identified under standards **source currents** and **patient sink current**.

Risk Current [108 ES1]
Any non-therapeutic current that may flow through the patient, medical staff, or bystander as a result of the use of electromedical apparatus.

Sink Current [108 ES1]
The current that flows into a device or any part thereof when an external voltage is applied to it.

Sink Current (Patient) [108 ES1]
Patient sink current is the current measured in a patient connection if a source of 120 volts (V), 60-Hz potential with respect to power (earth) ground is connected to that patient connection.

Source Current [108 ES1]
The undesirable electrical current that flows from any part of an electromedical apparatus to any other part or to power (earth) when no external voltages are applied.

Standards

Labeling Requirements [108]
Isolated patient connections – Patient connections that meet the requirements of this standard for isolated patient connections shall be identified as being isolated at the connector on the apparatus.

Information Manuals [108 ES1]
The manufacturer shall supply the user with operating and maintenance instructions that specify how the electromedical apparatus should be operated and maintained to prevent its risk current from increasing beyond the limits set by this standard for its particular risk current category. In addition, the manufacturer shall disclose the risk current category for which the apparatus is designed, and identify the specific limits defined by this standard for that category.

Risk Current Requirements (General) [108 ES1]
Electromedical apparatus shall meet the applicable risk current limits of this standard during normal operation, when ungrounded, and as specified herein. Fault currents are excluded from the risk current limits.

Risk Current (Apparatus Interconnection) [108 ES1]
Electromedical apparatus shall meet the risk current limits of this standard for its category when manufacture-designated auxiliary apparatus, modular apparatus, and/or accessories are attached in the quantity and combinations designated by the manufacturer. The manufacturer shall supply the user, and label the apparatus with limitations and directions for the interconnection of modular apparatus, accessories, and auxiliary apparatus and for the use of convenience receptacles so that the risk current limits set by this standard for its category are not exceeded.

Risk Current (Sterilization) [108 ES1]
Electromedical apparatus shall meet the risk current limits of this standard for its category after exposure to any disinfection or sterilization process specified by the manufacturer.

Risk Current (Environmental Conditions) [108 ES1]
Electromedical apparatus shall meet the risk current limits of this standard after exposure to the non-operational environmental conditions and under the worst-case operating conditions specified by the manufacturer.

Source Current (Chassis Source Current) [108 ES1]
Chassis source current is that current measured between power (earth) ground and (a) exposed chassis, (b) exposed conductive hardware, (c) a 200 cm^2 foil in contact with the insulating enclosure, or (d) the grounding conductor for the insulating enclosed, for any combination of the following conditions:

1. Utility electrical supply polarity normal and reverse
2. Apparatus power switch on and off
3. Ground open and intact

Source Current (Patient Source Current) [108 ES1]
Patient source current is the current measured between any individual patient connection and (a) power (earth) ground, (b) exposed electrically conductive surfaces or hardware, (c) a 200 cm^2 foil in contact with the insulating enclosure, or (d) any other patient connection; and between all patient connections connected together and (a) power (earth) ground,

(b) exposed electrically conductive surfaces or hardware, or (c) a 200 cm^2 foil in contact with the insulating enclosure, for any combination of the following conditions:

1. Utility electrical supply polarity normal and reverse
2. Apparatus power switch on and off
3. Ground open and intact

Grounding Resistance [108, 110]

AAMI Leakage Current		
	ANSI/AAMI	Comments
Chassis, fixed equipment	5 ma	
Chassis, fixed equipment	100 ua	With Ground Intact
Chassis, patient contact	100 ua	
Chassis, patient contact	500 ua	
Chassis, patient contact	100 ua	With Ground Intact
Patient Leadwire, Isolated	10 ua	At device
Patient Leadwire, nonisolated	50 ua	
Patient Leadwire, isolation (sink current)	10 ua 20 ua	At device At cable end

Table 1.1 – AAMI Leakage Current

NFPA 99 Leakage Current		
	NFPA	Comments
Chassis, fixed equipment	5 ma	
Chassis, patient contact	300 ua	
Chassis, patient contact	300 – 500 ua	With ground intact, regular testing
Patient Leadwire – all to ground, isolated	100 ua	
Patient Leadwire – single to ground, isolated	10 ua	With ground
Patient Leadwire – single to ground, isolated	50 ua	Without ground
Patient Leadwire, isolation (sink current)	50 ua	
Patient Leadwire, nonisolation (between leads)	50 ua	

Table 1.2 – NFPA 99 Leakage Current

Electrical Receptacles, Patient Care Areas		
Ground Impedance, Existing systems	0.2 ohms	
Ground Impedance, New construction	0.1 ohms	
Retention force, Ground Blade	115g (4oz)	

Table 1.3 – Electrical Receptacles, Patient care Areas

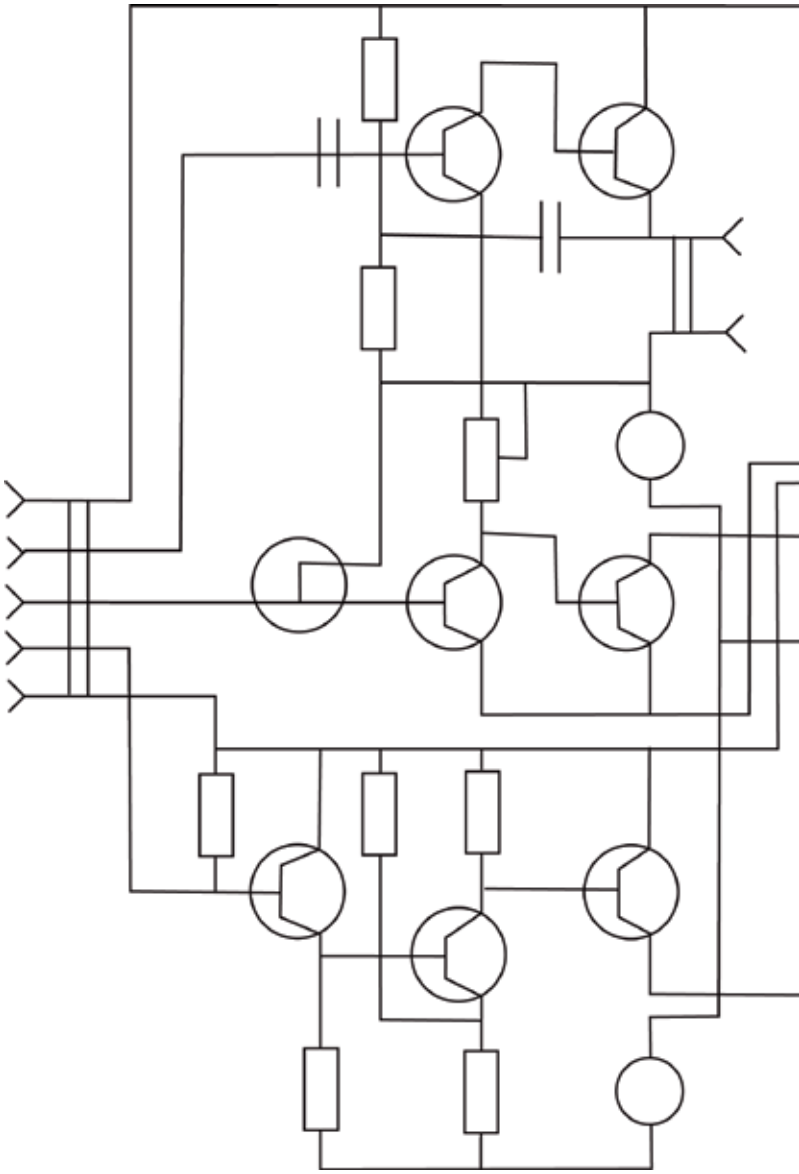
Receptacle Indicators	
Hospital Grade	All receptacles shall be listed hospital grade and so identified.
Emergency System	The cover plates for the electrical receptacles or the electrical receptacles themselves supplied from the emergency system shall have a distinctive color or marking so as to be readily identifiable.
Isolated Ground	Receptacles intended for the reduction of electrical noise (electromagnetic interference) shall be identified by an orange color or an orange triangle located on the face of the receptacle.
Surge Protection	

Table 1.4 – Receptacle Indicators

Ground Fault Circuit Interrupter (GFCI)		
Trip Current	5 ma	

Table 1.5 – Ground Fault Circuit Interrupter (GFCI)

02
Electrical Circuits



2 – Electrical Circuits

AC

See **Alternating Current**.

Alternating Current (ac) [245]

Alternating Current (ac) waveforms are time-varying symmetrical signals, alternating between two prescribed levels in a set time sequence.

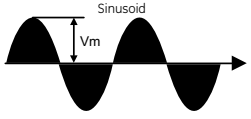
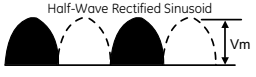
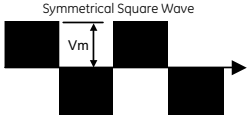
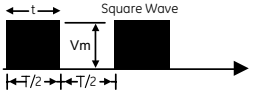
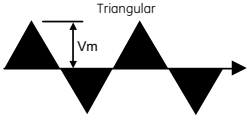
Waveform	$\frac{Vave}{Vm}$	$\frac{Veff}{Vm}$	FF	CF
Sinusoid 	0	$\frac{1}{\sqrt{2}}$	—	$\sqrt{2}$
Full-Wave Rectified Sinusoid	$\frac{2}{\pi}$	$\frac{1}{\sqrt{2}}$	$\frac{\pi}{2\sqrt{2}}$	$\sqrt{2}$
Half-Wave Rectified Sinusoid 	$\frac{1}{\pi}$	$\frac{1}{2}$	$\frac{\pi}{2}$	2
Symmetrical Square Wave 	0	1	—	1
Square Wave 	$\frac{t}{T}$	$\sqrt{\frac{t}{T}}$	$\sqrt{\frac{t}{T}}$	$\sqrt{\frac{t}{T}}$
Triangular 	0	$\frac{1}{\sqrt{3}}$	—	$\sqrt{3}$
Saw Tooth (and Triangular)	$\frac{1}{2}$	$\frac{1}{\sqrt{3}}$	$\frac{2}{\sqrt{3}}$	$\sqrt{3}$

Table 2.1 – Alternating Waveform Characteristics

American Wire Gage (AWG) [245]

The wire table was designed primarily to standardize the size of wire produced by manufacturers throughout the United States. For every drop in three gage numbers, the area is doubled, and for every drop in 10 gage numbers, the area increases by a factor of 10. The AWG sizes are shown for solid round copper wire. A column indicating the maximum allowable current in amperes, as determined by the National Fire Protection Association, is also shown.

	AWG #	Area (CM)	Ω/1,000 ft at 20 degrees C	Maximum Allowable Current for RHW Insulation (A)*
4/0	0000	211,600	0.049	230
(3/0)	000	167,810	0.0618	200
(2/0)	00	133,080	0.078	175
(1/0)	0	105,530	0.0983	150
	1	83,694	0.124	130
	2	66,373	0.1563	115
	3	52,634	0.197	100
	4	41,742	0.2485	85
	5	33,102	0.3133	-
	6	26,250	0.3951	65
	7	20,816	0.4982	-
	8	16,509	0.6282	50
	9	13,094	0.7921	-
	10	10,381	0.9989	30
	11	8,234.00	1.26	-
	12	6,529.00	1.588	20
	13	5,178.40	2.003	-
	14	4,106.80	2.525	15
	15	3,256.70	3.184	
	16	2,582.90	4.016	
	17	2,048.20	5.064	
	18	1,624.30	6.385	
	19	1,288.10	8.051	
	20	1,021.50	10.15	
	21		810.1	12.80
	22		642.4	16.14
	23		509.45	20.36
	24		404.01	25.67
	25		320.4	32.37
	26		254.1	40.81
	27		201.5	51.47
	28		159.79	64.90
	29		126.72	81.83
	30		100.5	103.2

*Not more then three conductors in raceway, cable, or direct burial.

Table 2.2 – AWG Sizes

Ampere, Amp [245]

One Ampere (A) is the flow of current caused by 6.242x1018 electrons drifting through a cross sectional area in one second.

Bridge Network [245]

A network configuration, typically having a diamond appearance, in which no two elements are in series or parallel.

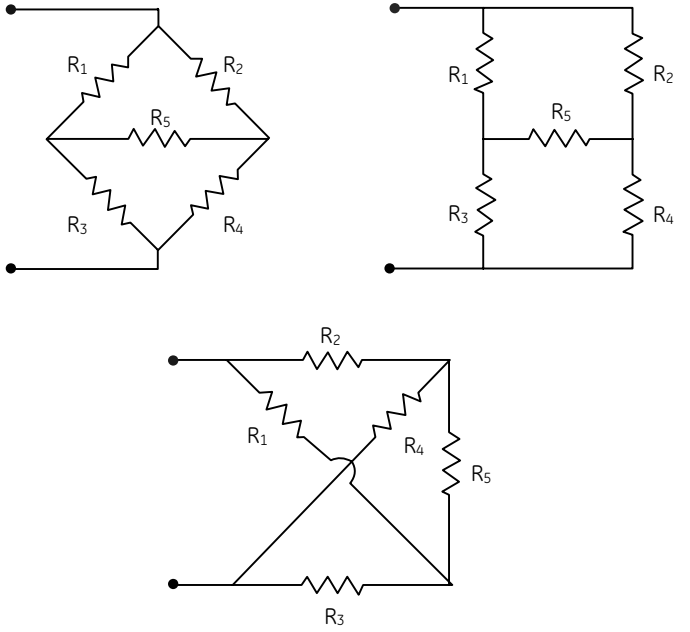


Fig 2.1 – Bridge Network

Capacitance [245]

A measure of a capacitor's ability to store a charge on its plates - its storage capacity. A capacitor has a capacitance of 1 Farad (F) if 1 Coulomb (C) of charge is deposited on the plates by a potential difference of 1 Volt (V) across the plates. Expressed as an equation, the capacitance is determined by:

$$C = \frac{Q}{V}$$

where:
C = capacitance (C)
Q = charge (C)
V = potential (V)

Capacitor [245]

A device that stores an electric charge. It is constructed from conducting surfaces separated by an insulator. If the conductors are connected across a voltage potential, charges will build up and create an electric field between them.

Conductance [245]

Conductance (G) is an indication of the relative ease with which current can be established in a material. It is the inverse of resistance ($G = \frac{1}{R}$) and has the units of Siemens (S).

R (Mahes to fix this)

Conductor [245]

A material that permits a generous flow of electrons with very little force (voltage) applied. Typical materials of various conductivity's include silver, copper, gold, and aluminum.

Coulomb [245]

A Coulomb (C) is the total charge associated with 6.242×10^{18} electrons.

Crest Factor [251]

Crest Factor is also known as the peak factor and amplitude factor. It is defined as:

$$CF = \frac{V_m}{V_{eff}}$$

Current [245]

The flow of charge passing through a cross-sectional area per unit of time, and is defined by the equation:

$$I = \frac{Q}{t}$$

where:
I = current (A)
Q = charge (C)
t = time(s)

By convention, current moves in a direction opposite to the flow of electrons. This is referred to as conventional flow.

Current Divider [245]

In a parallel circuit, the current through the resistive elements

will divide as the inverse ratio of their resistance levels, and the sum of the currents through the parallel resistors will equal the applied current. Therefore, by applying ohms law to these statements, it can be seen that for two parallel branches, the current through either branch is equal to the product of the other parallel resistor divided by the sum (not parallel resistance) of the two parallel resistances.

$$I_2 = \left(\frac{R_1}{R_1 + R_2}\right)$$

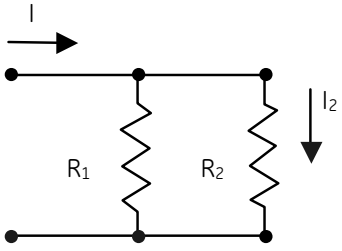


Fig 2.2 – Current Driver

Cycle [245]

The portion of an ac waveform contained in one period of time.

D'Arsonval Meter [251]

The d'Arsonval meter (also known as a galvanometer or permanent magnet moving coil mechanism) is essentially a current-measuring device. Current flowing through a coil creates a magnetic field that interacts with the field from a permanent magnet to produce a torque to move the indicator needle. The meter can be used to measure current or voltage depending on how an additional resistor is connected to the basic meter coil.

DC

See **Direct Current**.

$$R_1 = \frac{R_a R_c}{R_a + R_b + R_c}$$

$$R_2 = \frac{R_a R_b}{R_a + R_b + R}$$

$$R_3 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R_a = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_3}$$

$$R_b = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_1}$$

$$R_c = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_2}$$

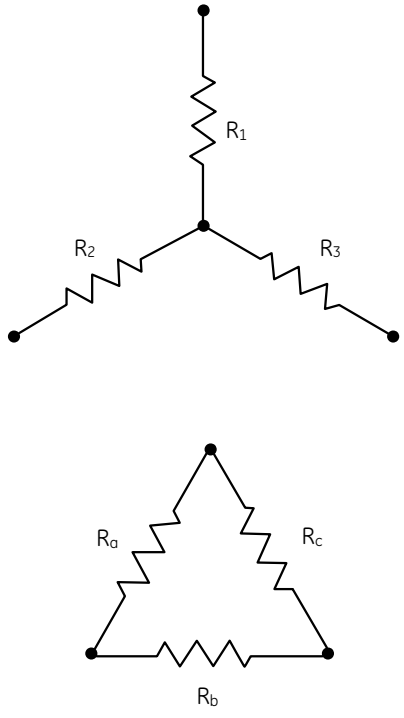


Fig 2.3 – Delta Wye Transformation [245]

Direct Current [245]

Current in a circuit in which the flow of charge does not vary in either magnitude or direction.

Electron Charge [245]

The charge associated with one electron is 1.6×10^{-19} C.

Energy [245]

The amount of power used over a period of time. It may be defined by:

$$W = Pt \quad \text{where: } W = \text{energy (W-s, J)}$$
$$P = \text{power (W)}$$
$$t = \text{time (s)}$$

For most practical purposes, W-s is too small a quantity, so

energy may be defined also in terms of watt-hour (W-h) or kilowatt-hour (kW-h).

Form Factor [251]

$$FF = \frac{V_{eff}}{V_{ave}}$$

Frequency [245]

The number of oscillations per second of a particular current or voltage waveform. The unit of frequency is Hertz (Hz).

$$1Hz = 1\frac{cycle}{second}$$

Frequency Spectrum [245]

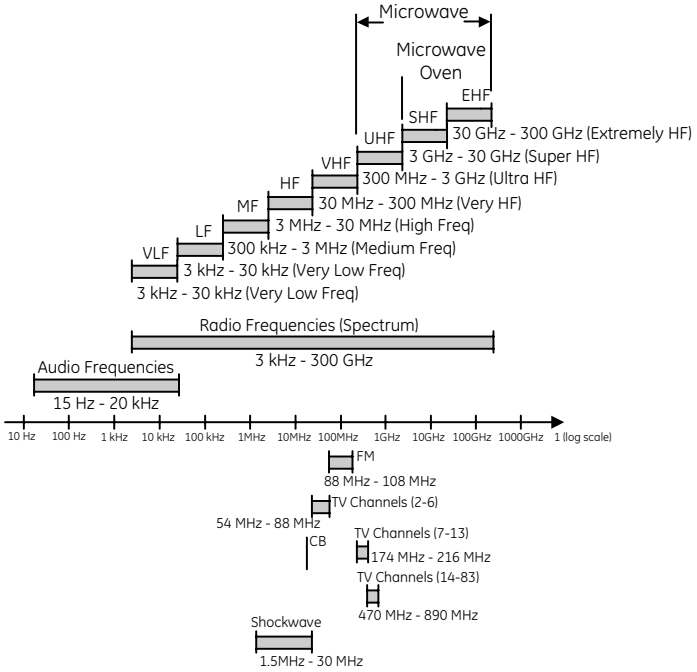

Microwave
Microwave Oven
EHF
SHF
30 GHz - 300 GHz (Extremely HF)
UHF
3 GHz - 30 GHz (Super HF)
VHF
300 MHz - 3 GHz (Ultra HF)
HF
30 MHz - 300 MHz (Very HF)
MF
3 MHz - 30 MHz (High Freq)
LF
300 kHz - 3 MHz (Medium Freq)
VLF
3 kHz - 30 kHz (Very Low Freq)
3 kHz - 30 kHz (Very Low Freq)
Radio Frequencies (Spectrum)
3 kHz - 300 GHz
Audio Frequencies
15 Hz - 20 kHz
10 Hz 100 Hz 1 kHz 10 kHz 100 kHz 1MHz 10MHz 100MHz 1GHz 10GHz 100GHz 1000GHz 1 (log scale)
FM
88 MHz - 108 MHz
TV Channels (2-6)
54 MHz - 88 MHz
CB
TV Channels (7-13)
174 MHz - 216 MHz
TV Channels (14-83)
470 MHz - 890 MHz
Shockwave
1.5MHz - 30 MHz

Fig 2.4 – Frequency Spectrum [245]

Galvanometer

See **D'Arsonval Meter**.

Impedance [271]

Impedance (Z) is the total opposition to current flow caused by resistance, and **inductive and capacitive reactance**. Because inductive and capacitive reactance's are sensitive to frequency changes, impedance is also sensitive to frequency changes.

Inductor [245]

An inductor is basically a coil of wire. When connected across a voltage source, current begins to flow in the coil, establishing a magnetic field that opposes current changes.

Insulator [245]

A material that requires a large potential (voltage) to establish a measurable current level. The level of insulation is measured in kV/cm. Common insulators include glass, rubber, bakelite, porcelain, and air.

Kirchoff's Current Law [245]

Kirchoff's current law states that the algebraic sum of the currents entering and leaving a junction (node) is zero. In other words, the sum of the currents entering a node equals the sum of the currents leaving the node.

Kirchoff's Voltage Law [245]

Kirchoff's Voltage Law (KVL) states that the algebraic sum of the potential rises and drops around a closed loop (or path) is zero. In other words, the sum of the potential rises will equal the sum of the potential drops around a closed path.

Maximum Power Transfer [245]

A load will receive maximum power from a linear bilateral DC network when its total resistive value is exactly equal to the equivalent (Thevenin or source) resistance of the network as seen by the load.

Ohm's Law [245]
Ohm's law states that for a fixed resistance, the amount of current flowing through the device is directly proportional to the amount of voltage (pressure) imposed across the device, and is defined by the equation:

$V = IR$ where: V = voltage (V)
I = current (A)
R = resistance (Ω)

Open Circuit [245]
Two isolated terminals not connected by an element of any kind. An open circuit can have a voltage across its terminals, but the current is always zero.

Parallel Circuit [245]
Elements or branches are in parallel if they have two points in common. Elements in parallel have the same voltage across them.

Peak Amplitude [245]
The maximum value of an ac waveform as measured from its average or mean value.

Peak Value [245]
The maximum instantaneous value of an ac waveform as measured from the zero-volt level.

Period [245]
The time interval between successive repetitions of a periodic (ac) waveform.

Photoconductive Cell [245]
A two-terminal device whose resistance is determined by the incident light applied to the exposed surface.

Potentiometer [245]
A three-terminal device through which potential levels can be varied in a linear or non-linear manner.

Power [245]
An indication of how much work can be done in a specified amount of time, or a rate of doing work. It is determined by:

$P = \frac{W}{t}$ where: P = Power (W or J/s)
W = energy (J)
t = time(s)

The power delivered to, or absorbed by, an electrical device or system can be found by substituting in the equation for energy and current, and obtaining:

$P = IV$

By substitution of Ohm's law, power in an electrical circuit can also be found by:

$P = I^2R$ or $P = \frac{V^2}{R}$

Reactance [245]
The opposition of an inductor or capacitor to the flow of charge that results in the continual exchange of energy between the circuit and magnetic field of an inductor or the electric field of a capacitor.

Reactance, Capacitive [245]
Capacitive reactance (XC) is the opposition to the flow of charge, which results in continual interchange of energy between the source and the electric field of the capacitor. The capacitor does not dissipate energy in any form.

$$X_C = \frac{1}{2\pi fC} = \frac{1}{\omega C}$$

Reactance, Inductive [245]
Capacitive reactance (XL) is the opposition to current, which results in continual interchange of energy between the source

and the magnetic field of the inductor. The inductor does not dissipate energy in any form.

$$X_L = 2\pi fL = wL$$

Resistance [245]

The opposition in a material to the flow of electrons that converts electrical energy into heat is the resistance of the material. At a constant temperature, the resistance of a material with a uniform cross sectional area is:

$$R = \rho \frac{l}{A}$$ where: R = resistance (ohm)
ρ = resistivity
l = length
A = cross-sectional area

Resistance, Parallel [245]

The total resistance in a parallel circuit is always less than the value of the smallest resistor, and can be found by:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \text{ --- } + \frac{1}{R_N}$$

For exactly two resistors in parallel, the total resistance is the product of the two divided by their sum, as:

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

Resistance, Series [245]

The total resistance of a series circuit is the sum of the individual resistors, and can be found by:

$$R_T = R_1 + R_2 + R_3 \text{ --- } + R_N$$

Resistivity [245]

Resistivity (ρ) is a proportionality constant between the resistance of a material and its physical dimensions.

Material	$\rho \left(\frac{CM - \Omega}{ft}\right)$ @ 20°C
Silver	9.9
Copper	10.37
Gold	14.7
Aluminum	17
Tungsten	33
Nickel	47
Iron	74
Constantan	295
Nichrome	600
Calorite	720
Carbon	21,000.00

Table 2.3 - Resistivity

Resistor [245]

A fixed value, molded composition resistor has four or five color bands printed on one end of the outer casing to identify its value. The first and second bands represent the first and second digits, respectively. The third band determines the power of ten multiplier (or the number of zeros) for the first two digits. The fourth band is the manufacturer's tolerance; if this band is omitted, the tolerance is assumed to be 20%. The fifth band is a reliability factor, which gives the percentage of failure per 1,000 hours of use.

Color	Digit (Band 1-2)	Multiplier (Band 3)	Tolerance (Band 4)	Reliability (Band 5)
Black	0	10^0	1%	
Brown	1	10^1	2%	1%
Red	2	10^2		0.10%
Orange	3	10^3		0.01%
Yellow	4	10^4		0.00%
Green	5	10^5		
Blue	6	10^6		
Violet	7	10^7		
Gray	8	10^8		
White	9	10^9		
Gold		10^1	5%	
Silver		10^2	10%	

Table 2.4 – Resistor (Color Bands)

Resonance [245]
A condition established by the application of a particular frequency (resonant frequency) to a series or parallel L-C network. The transfer of power to the system is a maximum and, for frequencies above and below, the power drops off to significantly lower levels.

Rheostat [245]
A device through whose terminal resistance can be varied in a linear or non-linear manner. This device is also traditionally referred to as a potentiometer.

RMS
See **Voltage, Effective**.

Semiconductor [245]
A material having a conductance value between that of an insulator and that of a conductor. It is of significant importance in the manufacture of semiconductor electrical devices.

Series Circuit [245]
Elements are in series if they have only one point in common that is not connected to any other current-carrying element in the network. Elements in series have the same current flowing through them.

Short Circuit [245]
A direct connection of zero resistance across an element or series of elements. A short circuit can carry any level of current, but the voltage across its terminals is always zero.

Superconductor [245]
The conductors of electric charge that, for all practical purposes, have zero resistance.

Thermistor [245]
A passive two-terminal device whose resistance is temperature sensitive. A thermistor may be a Positive Temperature Coefficient (PTC), where the resistance increases with an increase in temperature; or Negative Temperature Coefficient (NTC) where the resistance decreases with an increase in temperature.

Thermocouple [251]
An electromotive force known as Seebeck Voltage can be obtained by joining the ends of two dissimilar wires (e.g., iron and constantan), and then keeping the two junctions at different temperatures. Two wires joined in this manner form a thermocouple, and the voltage generation is known as the thermoelectric effect. The output of a thermocouple is typically in the millivolt range.

Thermopile [251]
A device constructed as an array of thermocouples (in series or in parallel) to generate a larger voltage or current.

Thevenin's Theorem [251]
Thevenin's theorem says that a linear, two-terminal network, with dependent and independent sources can be

represented by a Thevenin equivalent circuit, consisting of a voltage source in series with a resistor. The Thevenin equivalent voltage, V_{th}, is the open circuit voltage. The Thevenin equivalent resistance, R_{th}, is the resistance across the terminals when all independent sources are set to zero (short-circuiting voltage sources and open-circuiting current sources).

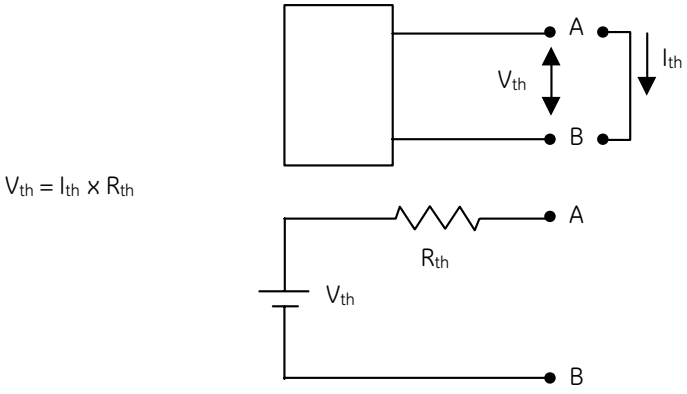


Fig 2.5 – Thevenin Equivalent Circuit

Varistor [245]

Varistors are voltage-dependent, non-linear resistors used to suppress high voltage transients. The device acts essentially like an open-circuit for voltages less than the firing voltage, and like a small resistance (short-circuit) when the voltage attempts to exceed the firing voltage.

Voltage [245]

The flow of charge (current) is established by an external pressure or potential energy. A potential difference of 1 Volt (V) exists between two points if 1 Joule (J) of energy is exchanged in moving 1 Coulomb (C) of charge between the two points. The potential can be determined by:

$$V = \frac{W}{Q}$$

where: V = potential (V)
W = energy expended (J)
Q = charge (C)

Voltage Divider [245]

In a series circuit, the voltage across the resistive elements will divide as the magnitude of the resistance levels, and the sum of the voltage drops across the series resistors will equal the applied voltage. Therefore, by applying Ohms law to these statements, it can be seen that the voltage across a resistor in a series circuit is equal to the value of that resistor times the total impressed voltage across the series elements, divided by the total resistance of the series elements.

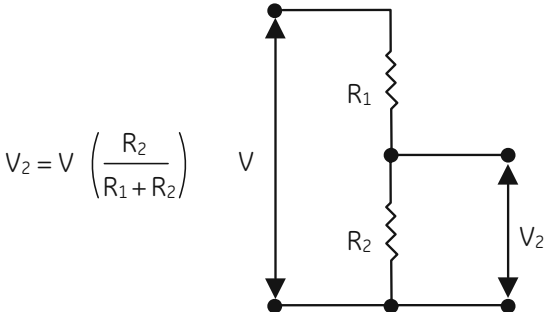


Fig 2.6 – Voltage Divider

Voltage, Average [245]

The average, value of an ac waveform is the equivalent dc component of that wave, and is the value of any current or voltage indicated on a dc meter. The average voltage of a periodic waveform can be determined by:

$$V_{ave} = \frac{1}{T}\int_0^T v\,(t)\,dt$$

The average value of a sinusoidal voltage is zero. The average value of other non-sinusoidal waves is in the table of **alternating waveform characteristics**.

Voltage, Effective [251]

The effective, or rms, value of an ac voltage is that value that produces the same heat in a resistive circuit as a dc voltage of the same value. In other words, equal amounts of dc voltage and effective voltage produce equal power across resistors of

equal value. The effective voltage of a periodic waveform can be determined by:

$$V_{eff} = \sqrt{V_{ave} = \frac{1}{T}\int_0^T V^2\,(t)\,dt}$$

The effective value of a sinusoidal voltage is $\frac{1}{\sqrt{2}}$ Vm or 0.707 Vm. The effective value of other non-sinusoidal waves is in the table of alternating waveform characteristics.

Voltage, Peak To Peak [245]

The full voltage between the positive and negative peaks of an ac waveform or the sum of the magnitude of the positive and negative peaks.

Wheatstone Bridge [271]

A bridge network that can be used to measure small changes in resistance.

$$Vout = Vin\left(\frac{R_3}{R_1 + R_3} - \frac{R_4}{R_2 + R_4}\right)$$

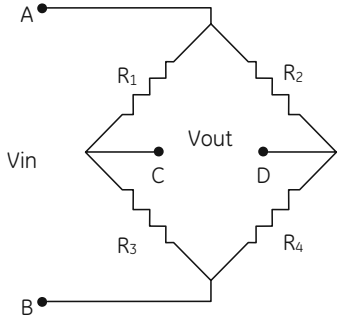


Fig 2.7 – Wheatstone Bridge

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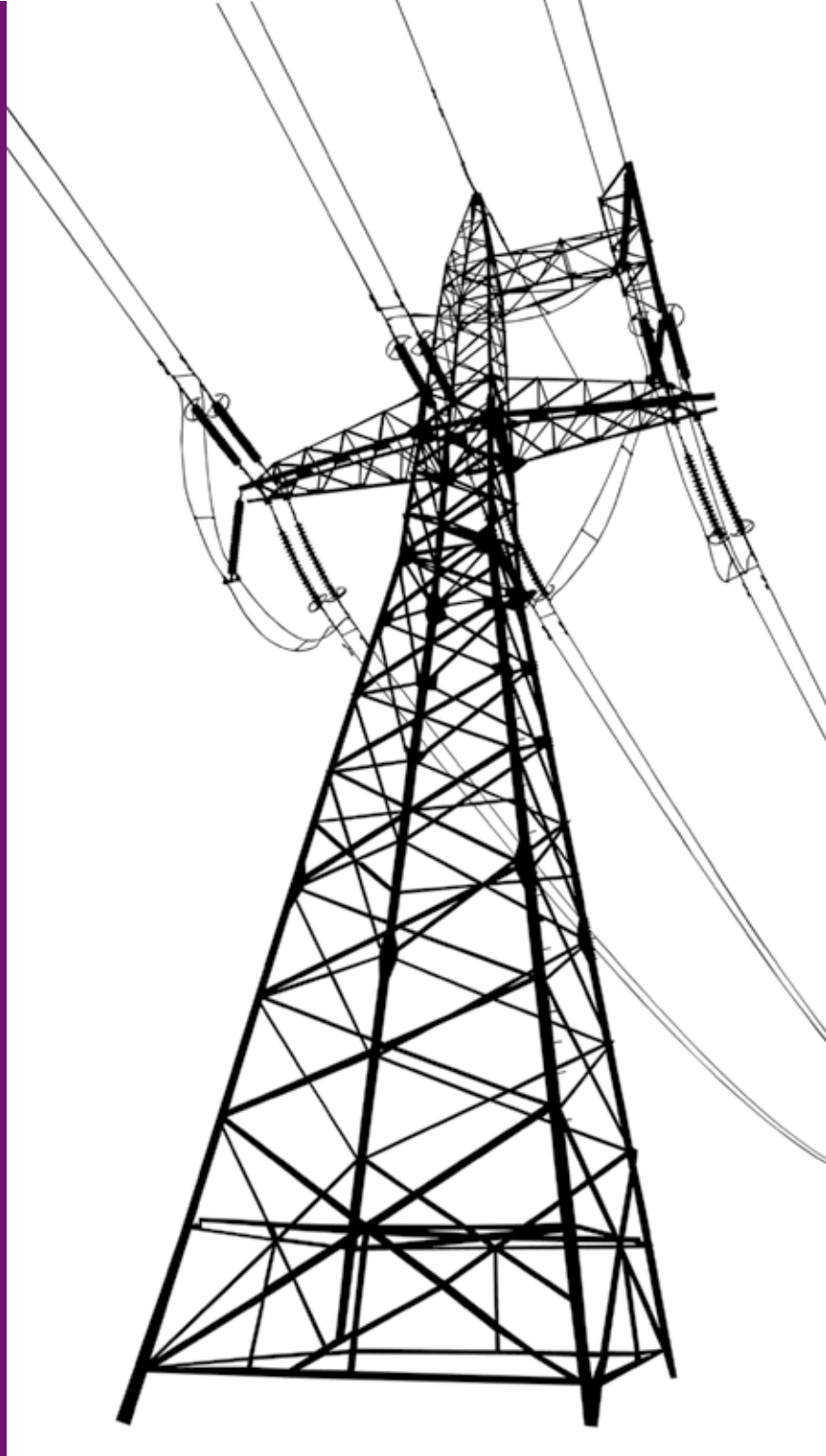
03
Power Distribution



3 – Power Distribution

Blackout [251]
A defect in the ac voltage waveform characterized by a complete failure that lasts more than one cycle.

Brownout [251]
A defect in the ac voltage waveform characterized by a decrease in the steady-state voltage amplitude.

Chronic Overvoltage [251]
A defect in the ac voltage waveform characterized by an increase in the steady-state voltage amplitude that lasts for a long time.

Dip
See **Sag**.

Electrical Shock Hazard [248]
A condition which could result in injury or electrocution to a person, caused by the flow of electrical current through the body.

Emergency System [110]
A system of circuits and equipment intended to supply alternate power to a limited number of prescribed functions vital to the protection of life and safety, with automatic restoration of electrical power within 10 seconds of power interruption.

Equipment System [110]
A system of circuits and equipment arranged for automatic or manual connection to the alternate power source; serves primarily three-phase power equipment.

Essential Electrical System [110]
A system comprised of alternate sources of power and all connected distribution systems and ancillary equipment, designed to ensure continuity of electrical power to designated areas and functions of a health care facility during disruption of normal power sources; also designed to minimize disruption within the internal wiring system.

Failure [110]
An incident that increases the hazard to personnel or patients or affects the safe functioning of electric appliances or devices. It includes failure of a component, loss of normal protective paths such as grounding, and short circuits or faults between energized conductors and the chassis.

Fault Current [110]
A current in an accidental connection between an energized and a grounded or other conductive element, resulting from a failure of insulation, spacing, or containment of conductors.

Fault Hazard Current [110]
The fault hazard current is the **hazard current** of a given **isolated power system**, with all devices connected except the **line isolation monitor**.

GFCI
See **Ground Fault Circuit Interrupter**.

Ground [116]
A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

Ground Fault [248]
An unintentional electrical path to ground between a part operating normally at some potential to ground, and ground.

Ground Fault Circuit Interrupter [248]
A ground fault circuit interrupter (GFCI) is a device intended for the protection of personnel. It de-energizes a circuit or portion thereof within an established period of time when a current to ground exceeds some predetermined value that is less than

that required to operate the overcurrent protective device of the supply circuit.

Grounded [116]
Connected to earth or to some conducting body that serves in place of earth.

Grounded Conductor [116]
A system or circuit conductor that is intentionally **grounded**.

Grounding Bus [249]
A protective ground network for establishing a uniform potential in and about the structure. It is tied solidly to the **grounding electrodes**. It must be of adequate size for the installation, and should run to various points in the building for convenient use.

Grounding Conductor, Equipment [116, 248]
The equipment grounding conductor is the conductor used to connect the noncurrent-carrying metal parts of equipment, raceways, and other enclosures to the system **grounded conductor** and/or the **grounding electrode conductor** at the service equipment or at the source of a separately derived system. The equipment grounding conductor path must be permanent and continuous, have ample capacity to conduct safely any currents likely to be imposed on it, and be of the lowest practical impedance.

Grounding Conductor [248]
The conductor used to connect the **grounding electrode** to the equipment grounding conductor and/or to the grounded conductor of the circuit at the service equipment, or at the source of a separately derived system.

Grounding Electrode [249]
A conductor embedded in the earth for the purpose of dissipating into the earth the currents conducted to it via connecting **grounding conductors**.

Grounding System [110]
A grounding system is a system of conductors that provides a low-impedance return path for leakage and fault currents.

Hazard Current [110]
For a given set of connections in an **isolated power system**, the hazard current is the total current through a low impedance if it were connected between isolated conductor and ground. The various hazard currents are **fault hazard current**, **monitor hazard current**, and **total hazard current**.

Horse Power [249]
A foot-pound-second unit of power, equivalent to 550 foot-pounds per second, or 746 watts.

Hp
See **Horse Power**.

Hunting [251]
A defect in the ac voltage waveform characterized by a frequency deviation resulting from irregular generation (i.e., uneven speed of the generator's prime mover).

IEEE Device Numbers and Functions [250]
The devices in switching equipment are referred to by numbers, according to the functions they perform. These numbers are based on a system that has been adopted as standard for automatic switchgear by IEEE. This system is used on connection diagrams, in instruction books, and in specifications.

Device No.	Function
1	Master Element
2	Time-Delay Starting or Closing Relay
3	Checking or Interlocking Relay
4	Master Contactor
5	Stopping Device
6	Starting Circuit Breaker

7	Anode Circuit Breaker
8	Control Power Disconnecting Device
9	Reversing Device
10	Unit Sequence Switch
11	(Reserved for Future Application)
12	Overspeed Device
13	Synchronous-Speed Device
14	Underspeed Device
15	Speed or Frequency Matching Device
16	(Reserved for Future Application)
17	Shunting or Discharge Switch
18	Accelerating or Decelerating Device
19	Starting to Run Transition Contactor
20	Electrically Operated Valve
21	Distance Relay
22	Equalizer Circuit Breaker
23	Temperature Control Device
24	(Reserved for Future Application)
25	Synchronizing or Synchronism Check
26	Apparatus Thermal Device
27	Undervoltage Relay
28	(Reserved for Future Application)
29	Isolating Contactor
30	Annunciator Relay
31	Separate Excitation Device
32	Directional Power Relay
33	Position Switch
34	Motor-Operated Sequence Switch
35	Brush-Operating or Slip-Ring Short-Circuiting Device
36	Polarity Device
37	Undercurrent or Underpower Relay
38	Bearing Protective Device
39	(Reserved for Future Application)
40	Field Relay
41	Field Circuit Breaker
42	Running Circuit Breaker
43	Manual Transfer or Selector Device
44	Unit Sequence Starting Relay

45	(Reserved for Future Application)
46	Reverse-Phase Balance Current Relay
47	Phase-Sequence Voltage Relay
48	Incomplete Sequence Relay
49	Machine or Transformer Thermal Relay
50	Instantaneous Overcurrent or Rate-of-Rise Relay
51	AC Time Overcurrent Relay
52	AC Circuit Breaker
53	Exciter or DC Generator Relay
54	High-Speed DC Circuit Breaker
55	Power-Factor Relay
56	Field Application Relay
57	Short-Circuiting or Grounding Device
58	Power Rectifier Misfire Relay
59	Overvoltage Relay
60	Voltage Balance Relay
61	Current Balance Relay
62	Time Delay Stopping or Opening Relay
63	Liquid or Gas Pressure Level or Flow Relay
64	Ground Protective Relay
65	Governor
66	Notching or Jogging Device
67	AC Directional Overcurrent Relay
68	Blocking Relay
69	Permissive Control Device
70	Electrically Operated Rheostat
71	(Reserved for Future Application)
72	DC Circuit Breaker
73	Load Resistor Contactor
74	Alarm Relay
75	Position-Changing Mechanism
76	DC Overcurrent Relay
77	Pulse Transmitter
78	Phase-Angle Measuring or Out-of-Step Protective Relay
79	AC Reclosing Relay
80	(Reserved for Future Application)
81	Frequency Relay
82	DC Reclosing Relay

83	Automatic Selective Control or Transfer Relay
84	Operating Mechanism
85	Carrier or Pilot-Wire Receiver Relay
86	Locking-Out Relay
87	Differential Protective Relay
88	Auxillary Motor or Motor Generator
89	Line Switch
90	Regulating Device
91	Voltage Directional Relay
92	Voltage and Power Directional Relay
93	Field-Changing Contactor
94	Tripping or Trip-Free Relay
95	(Reserved for Future Application)
96	
97	
98	
99	

Table 3.1 – IEEE Device Numbers and Functions

Isolated Power System [110]

An isolated power system is a system comprising an **isolation transformer** or its equivalent, a **line isolation monitor**, and its ungrounded circuit connectors.

Isolation Transformer [110]

A transformer of the multiple-winding type, with the primary and secondary windings physically separated, that inductively couples its ungrounded secondary winding to the grounded feeder system that energizes its primary winding.

Leakage Current [110]

Any current, including capacitively coupled current, not intended to be applied to the patient, that is conveyed from exposed metal parts of an appliance to ground or to other accessible parts of an appliance.

Life Safety Branch [110]

A subsystem of the emergency system, consisting of feeders and branch circuits, meeting requirements of Article 700 of NFPA 70, *National Electric Code*, and intended to provide adequate power needs to ensure safety to patients and personnel, and automatically connected to alternate power sources during interruption of the normal power source.

LIM

See **Line Isolation Monitor**.

Line Isolation Monitor [110]

A line isolation monitor is a test instrument designed to continually check the balanced and unbalanced impedance from each line of an isolated circuit to ground. It is equipped with a built-in test circuit to exercise the alarm without adding to the leakage current hazard.

Line Noise [251]

A defect in the ac voltage waveform characterized by interference that appears as small magnitude variations riding on the regular waveform, caused by radio frequency and electromagnetic sources.

Monitor Hazard Current [110]

The monitor hazard current is the **hazard current** in given **isolated power system** of the **line isolation monitor** alone.

NFPA 70 [116]

National Electric Code Handbook covers installations of electric conductors and equipment within or on public and private buildings or other structures, including mobile homes, recreational vehicles, and floating buildings, and other premises such as yards, carnival, parking and other lots, and industrial substations.

NFPA 99 [110]

Standard for Health Care Facilities containing criteria to minimize the hazards of fire, explosion, and electricity in health care facilities. These criteria include performance, maintenance, testing, and safe practices for facilities, mate-

rial, equipment, and appliances, and include other hazards associated with the primary hazards.

NFPA 101 [114]

Life Safety Code Handbook establishes minimum requirements that will provide a reasonable degree of safety from fire in buildings and structures. It addresses those construction, protection and occupancy features necessary to minimize danger to life from fire, smoke, fumes, or panic.

One-Line Electrical Diagrams [250]

The one-line electrical diagram is a simplified power-system drawing that shows one line for each three-phase circuit. Since the normal operation of three-phase power systems balanced, and balanced three-phase systems are analyzed on a per-phase basis, it is redundant to draw more than one phase. The symbols used are in standard use to describe elements of power systems.

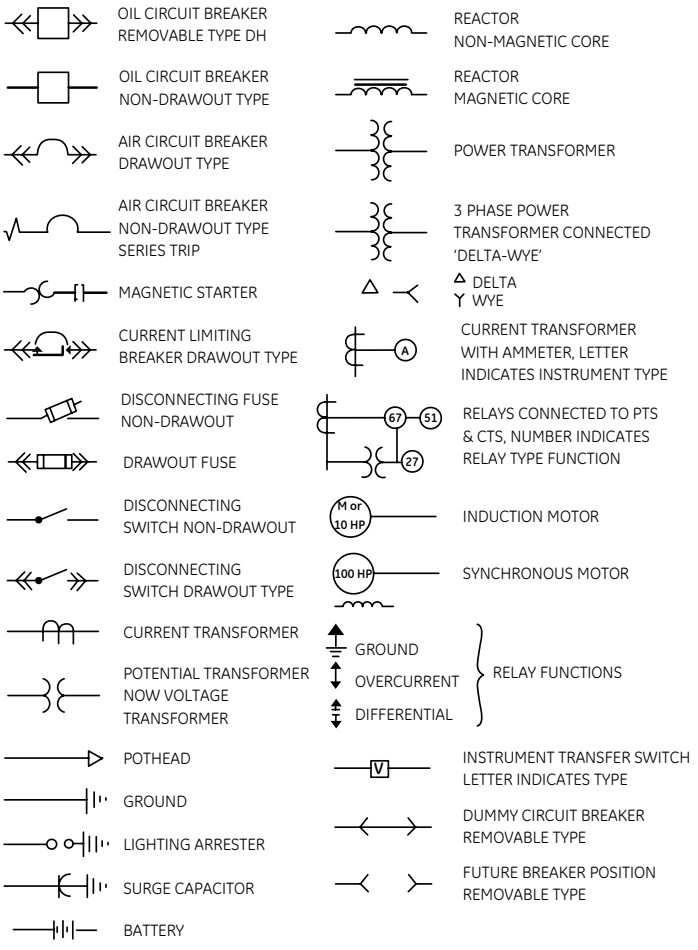


Fig 3.1 – Commonly Used Symbols for One-Line Electrical Diagrams

Patient Equipment Grounding Point [110]

A jack or terminal that serves as the collection point for redundant grounding of electric appliances serving a patient care vicinity or for grounding other items in order to eliminate electromagnetic interference problems.

Plug [110]

A device that, when inserting into a receptacle, establishes

connection between the conductors of the attached flexible cord and the conductors connected permanently to the receptacle.

Power Factor [271]

Power factor (PF) indicates how much power is actually being delivered to the load in an ac circuit. Mathematically, the power factor is:

PF = cos θ where θ is the phase angle of the circuit current and voltage

When these are in phase, θ = 0 and the power factor becomes 1, meaning that the product of the voltage and current is the actual power.

Quiet Ground [110]

A system of grounding conductors, insulated from portions of the conventional grounding of the power system, that interconnects the grounds of electric appliances for the purposes of improving immunity to electromagnetic noise.

Reactance

The component of impedance contributed by inductance or capacitance. The unit of reactance is ohms.

Reference Grounding Point [110]

A terminal bus that is the equipment **grounding bus**, or an extension of the equipment grounding bus, and is a convenient collection point for installed grounding wires or other bonding wires where used.

Sag [251]

A defect in the ac voltage waveform characterized by a disturbance (similar to a **brownout**, but of shorter duration) that occurs when the line voltage drops below approximately 80-85% of its rated voltage by one or more cycles.

Single-Line Electrical Diagram

See **One-Line Electrical Diagram**.

Spike [251]

A defect in the ac voltage waveform characterized by a high voltage (up to 6,000V or more), peak lasting approximately 100μS to one-half of a cycle.

Surge [251]

A defect in the ac voltage waveform characterized by a disturbance (similar to an overvoltage, but of much shorter duration) that occurs when the line voltage exceeds 110% of its rated voltage for one or more cycles.

Total Hazard Current [110]

The total hazard current is the **hazard current** of a given **isolated power system** with all devices, including the **line isolation monitor**, connected.

Transient [251]

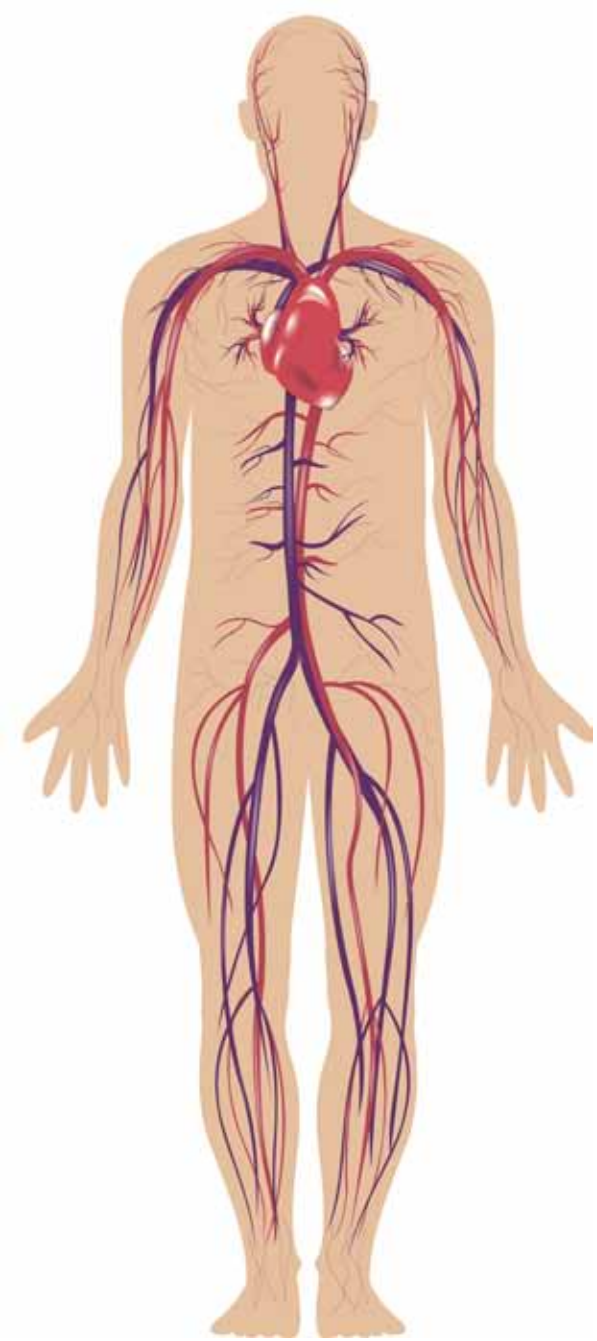
A defect in the ac voltage waveform characterized by a high voltage (up to 20,000V or more) peak lasting approximately 10 to 100μs.

To Find	Direct Current	Alternating Current	
		Single-Phase	Three-Phase
Amperes when horsepower is known	$\frac{hP \times 746}{E \times \eta}$	$\frac{hP \times 746}{E \times \eta \times PF}$	$\frac{1.73 \times hP \times 746}{E \times \eta \times PF}$
Amperes when kilowatts is known	$\frac{kW \times 1{,}000}{E}$	$\frac{kW \times 1{,}000}{E \times PF}$	$\frac{kW \times 1{,}000}{1.73 \times E \times PF}$
Amperes when kVA is known	-	$\frac{kVA \times 1{,}000}{E}$	$\frac{kVA \times 1{,}000}{1.73 \times E}$
Kilowatts	$\frac{I \times E}{1{,}000}$	$\frac{I \times E \times PF}{1{,}000}$	$\frac{I \times E \times 1.73 \times PF}{1{,}000}$
kVA	-	$\frac{I \times E}{1{,}000}$	$\frac{I \times E \times 1.73}{1{,}000}$
Horsepower (output)	$\frac{I \times E \times \eta}{746}$	$\frac{I \times E \times \eta \times PF}{746}$	$\frac{I \times E \times 1.73 \times \eta \times PF}{746}$

Note: η is the efficiency of a motor expressed as a decimal.
PF is power factor expressed as a decimal.
I is line current in amperes. E is voltage, line to line.

Table 3.2 – Formulae for Determining Amperes, HP, KW, and kVA

04
Cardiology and Circulation



4 - Cardiology and Circulation

Acidosis [234]
An abnormal increase in hydrogen ion concentration in the body resulting from an accumulation of acid or a loss of a base. It is indicated by a blood pH below 7.

Action Potential [172]
When a cell is stimulated, the membrane wall quickly changes, allowing it to become permeable to sodium ions. As sodium ions race into the cell, potassium ions rush out. The effect creates an action potential with the inside of the cell at a potential of 20 to 40 mV with reference to the outside. This action lasts only a few milliseconds before reversal occurs.

Afterload [235]
Resistance or impedance to ventricular outflow (emptying). Ventricular pressure must exceed this resistance in order to open the **aortic valve.**

Agonal Rhythm [172]
Terminal rhythm indication of a dying heart.

Alkalosis [172]
An elevated blood pH that is indicative of an acid base derangement, blood pH is greater than 7.45.

Anaphalactic Shock [172]
An allergic reaction creating a shock-like state.

Angina Pectoris [172]
A cardiac disease, which manifests as spasmodic attacks of intense constriction or suffocating pressure beneath the sternum, neck, jaw, or arms as a result of a deficient oxygen supply to the heart muscle.

Anterior [172]
The frontal portion of any structure.

Anoxia [234]
An abnormal condition characterized by a lack of oxygen. Anoxia may be local or systemic, and may be the result of an inadequate supply of oxygen to the respiratory system or inability of the blood to carry oxygen to the tissues, as in anemic anoxia, or of the tissues to absorb the oxygen from the circulation, as in histotoxic anoxia.

Aorta [234]
The aorta is the main trunk of the systemic arterial circulation. It starts at the aortic opening of the left ventricle, rises a short distance towards the neck, bends left and dorsally over the root of the left lung, descends within the thorax on the left side of the vertebral column, and passes through the aortic hiatus of the diaphragm into the abdominal cavity, where it branches into the two common iliac arteries.

Aortic Stenosis [172]
Narrowing of the aortic valve and its flow tract.

Aortic Valve [234]
The aortic valve is in the heart between the left ventricle and the aorta. It is composed of three semilunar cusps that close during **diastole** to prevent blood from flowing back into the left ventricle from the aorta.

APSP
See **Assisted Peak Systolic Pressure**.

Arrest [172]
The cessation of electrical or mechanical activity of all or part of the heart.

Arrhythmia [172]
Any non-normal cardiac rhythm. It may be sinus or **ectopic** in origin.

Arteriosclerosis [234]
Arteriosclerosis is a common arterial disorder characterized by thickening, loss of elasticity, and calcification of arterial walls, resulting in a decreased blood flow to the cerebrum and lower extremities.

Artifact [172]
Any unwanted spurious electrical activity identified while monitoring a signal.

Artificial Pacemaker
See **Pacemaker**.

Assisted Peak Systolic Pressure (APSP) [235]
The systolic pressure that reflects the action of the **intra-aortic balloon**. The reduction in systolic pressure demonstrates improved forward flow due to a decrease in **myocardial** oxygen demand.

Asystole (Ventricular) [172]
Absence of electrical activity of the heart, (cardiac arrest).

Atherosclerosis [234]
Atherosclerosis, s type of **arteriosclerosis**, is a common arterial disorder characterized by yellowish plaques of cholesterol, lipids, and cellular debris in the inner layers of the walls of large- and medium-sized arteries. The vessel walls become thick, fibrotic, and calcified, and the lumen narrows, resulting in a reduced blood flow to organs normally supplied by the artery.

Atherosclerosis, Coronary [172]
Thickening of the lining within the coronary arteries. This is due to lipid deposits called atheroma. The condition causes a narrowing of the vessels and reduces blood supply to the heart muscle.

Atria
See **Atrium**.

Atrial Fibrillation [234]
Disorganized, ineffective contractions originating in the atria at a rate of 350 to 600 bpm. Most notably, there is an absence of any P wave. Ventricular response is irregular.

Atrial Flutter [168]
A saw-tooth-shaped atrial wave (called F waves) occurring between 250 and 350 beats per minute. With a 300 bpm atrial wave, the AV node protects the ventricles by only allowing every fourth beat transmitted to them creating a 4:1 ratio of ventricular conduction.

Atrial Synchronized Pacemaker [172]
The initialization of ventricular depolarization by an artificial **pacemaker** occurring at a specific interval after P wave.

Atrial Tachycardia [168]
A regular heart rhythm with a rate between 160 and 250 beats per minute. This rhythm has a sudden onset and often terminates abruptly.

Atrioventricular (AV) Node [234]
An area of specialized cardiac muscle, located in the septal wall of the right atrium that receives the cardiac impulse from the **sinoatrial (SA) node** and conducts it to the **Bundle of His**.

Atrium [172]
One of the two hollow mass upper chambers (right atrium and left atrium) of the heart, comprised of homogenous cardiac muscle. The atrium receives blood from the veins, and fills the ventricles with blood during the cardiac cycle.

Augmentation [235]
The increase in pressure that occurs as a result of **intra-aortic balloon** inflation and blood volume displacement. See also **Peak Diastolic Pressure**.

Augmented Leads [164]

A method of summing two bipolar Leads with reference to a third. Two limb leads are summed and applied to the inverting input of an amplifier. The third lead is applied to the non-inverting amplifier input.

The augmented leads are AVR, AVL, and AVF.

- AVR: Right arm attached to non-inverting input, LA and LL summed.
- AVL: Left arm attached to non-inverting input, RA and LL summed.
- AVF: Left Leg attached to non-inverting input, RA and LA summed.

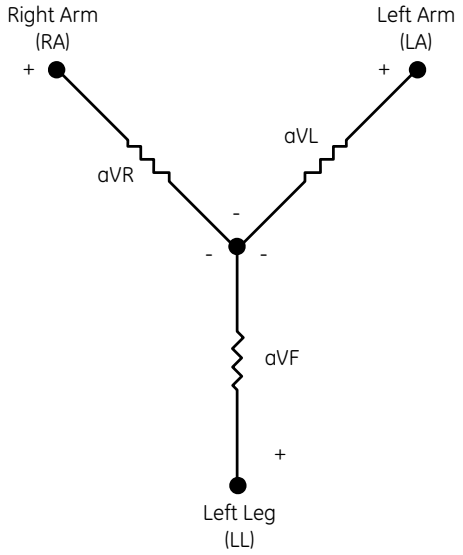


Fig 4.1 – Augmented Leads

Auscultation [234]

The act of listening for sounds within the body to evaluate the condition of the heart, blood vessels, lungs, pleura, intestines, or other organs, or to detect the fetal heart sound. Auscultation may be performed directly, but most commonly a **stethoscope** is used to determine the frequency, intensity, duration, and quality of the sounds.

Auscultatory Measurement [233]

Measurement of blood pressure in which a **sphygmomanometer**, an inflatable cuff attached to a mercury manometer, is wrapped around the arm and a **stethoscope** is placed over the brachial artery at the elbow.

Automaticity [168]

The ability of a cell to initiate a pulse.

Autonomic Nervous System [168]

Comprised of the **sympathetic** and **parasympathetic nerves**. The sympathetic system uses norepinephine as a stimulant and affects the atria and ventricles by increasing the following:

1. Rate of SA Node
2. Atrioventricular Conduction
3. Excitability
4. Force of Contraction

The parasympathetic system (vagus nerve) supplies the atria with acetylcholine, decreasing the same.

AV Node

See **Atrioventricular (AV) Node**.

Axis

See **Lead Axis.**

Axis Deviation [166, 172]

The mean direction of electrical forces in the frontal plane. One method used in determining **axis** is the hexaxial figure as shown.

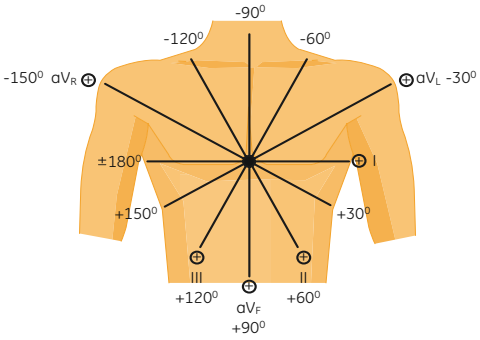


Fig 4.2 - The Hexaxial Figure

BAEDP

See **Balloon Aortic End Diastolic Pressure (BAEDP)**.

Balloon Aortic End Diastolic Pressure (BAEDP) [235]

The lowest pressure in the aorta that is created by the action of **intra-aortic balloon** deflation. The end result is a decrease in **afterload**.

Bigeminy [172]

A heart rhythm in which two closely spaced complexes are followed by an interval that repeats itself.

Bipolar Leads [164]

Lead configurations I, II, and III that measure the potential difference between two electrode sites. See **Einthoven Triangle**.

Bipolar Leads Configuration

See **Leads, Electrocardiographic With Axes**.

Blood Pressure (BP) [234]

The pressure exerted by the circulating volume of blood on the walls of the arteries, veins, and chambers of the heart.

Blood Pressure, Normal Values [231]

Pressure	Abbreviation	Normal Value (mmHg)
Systemic arterial		
Systolic	SP	90-140
Diastolic	DP	60-90
Mean	MAP	70-105
Pulmonary artery		
Systolic	PAS	15-30
Diastolic	PAD	4-12
Mean	MPA	9-16
Pulmonary capillary		
Wedge pressure *	PCWP	1-10
Right atrial *, central Venous *	RAP, CVP **	0-8
Right ventricle		
Systolic	RVSP	15-30
Diastolic	RVEDP	0-8
Left ventricle		
Systolic	LVSP	90-140
End diastolic	LVEDP	5-12

**PCWP, RAP, and CVP are listed as their mean values.*

***RAP and CVP refer to the same measurement and are used interchangeably.*

Table 4.1 – Blood Pressure, Normal Values

Body Surface Area (BSA) [230]

A measure of the size of a person, and is valuable in normalizing cardiac output. It can be obtained by the use of a nomogram such as the Dubois Body Surface Chart, which uses height and weight to obtain the body surface area. Units are in meters squared (m^2).

BP

See **Blood Pressure**.

Bradycardia (Sinus) [168]

Normal sinus rhythm with a heart rate under 60 beats per minute. It is also known as sinus bradycardia.

Bundle Branch [234]

A segment of a network of specialized conducting fibers that transmit electrical impulses within the ventricles. It is

a continuation of the **Bundle of His**, extending from the intraventricular **septum** of the heart. The AV bundle divides into a left and right branch, each going to its respective ventricle by passing down the septum and beneath the endocardium. Within the ventricles, the bundle branches terminate in the **Purkinje fibers**.

Bundle Branch Block [234]

An abnormal conduction of the cardiac impulse within the ventricles, resulting in an abnormally shaped QRS complex. It is commonly caused by **ischemia** or **necrosis** of the bundle branches, trauma (as a surgical manipulation), or mechanical compression of the branches by a tumor.

Bundle of His [172]

A portion of the conduction system of the heart arising from the AV node and dividing into branches on either side of the septum that ramify in either ventricle.

Cardiac Arrest [172]

Absence of cardiac activity.

Cardiac Catheterization [234]

Cardiac catheterization is a diagnostic procedure in which a catheter is introduced into a large vein, usually of an arm or leg, and threaded through the circulatory system to the heart. As the catheter tip is passed through the chambers and vessels of the heart, the pressure of the flow is monitored, and samples of the blood are taken to study the oxygen content.

Cardiac Cell, Electrophysiological Properties [168]

- Automaticity - The ability to initiate a pulse.
- Excitability - The ability to respond to an impulse.
- Conductivity - The ability to transmit an impulse.
- Contractility - The ability to respond with pumping action.
- U wave - late recovery of ventricular Purkinje fibers.

Cardiac Conduction System [164, 168]

- *SA node* - Normally the site of origin of electrical impulse, leading to depolarization of the atria.
- *AV node* - Causes a delay in conduction speed to allow atrial contents to move to the ventricles.
- *Bundle of His* - A conduction pathway located in the septum of the heart. This pathway, broken into two branches called the left bundle branch and the right bundle branch, allows for normal conduction between the atria and the ventricles.
- *Purkinje fibers* - A network of fibers covering the endocardial surfaces of both ventricles that direct the cardiac impulse into the ventricular **myocardium**, causing the ventricles to contract.

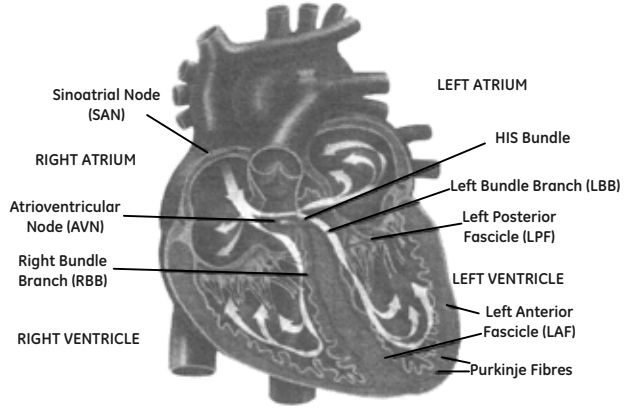


Fig 4.3 - Cardiac Conduction System

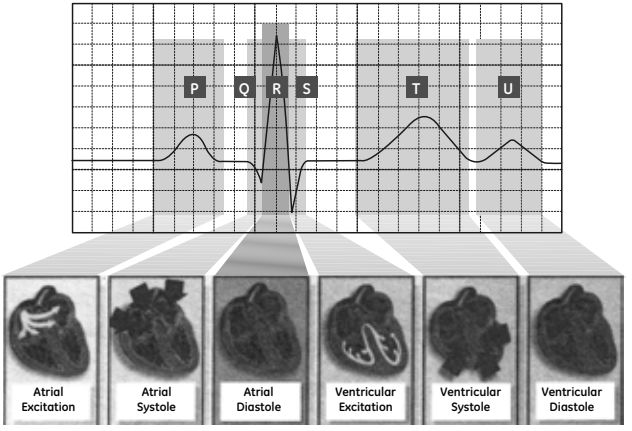


Fig 4.4 - Electrical and Mechanical Events

Cardiac Cycle [233]

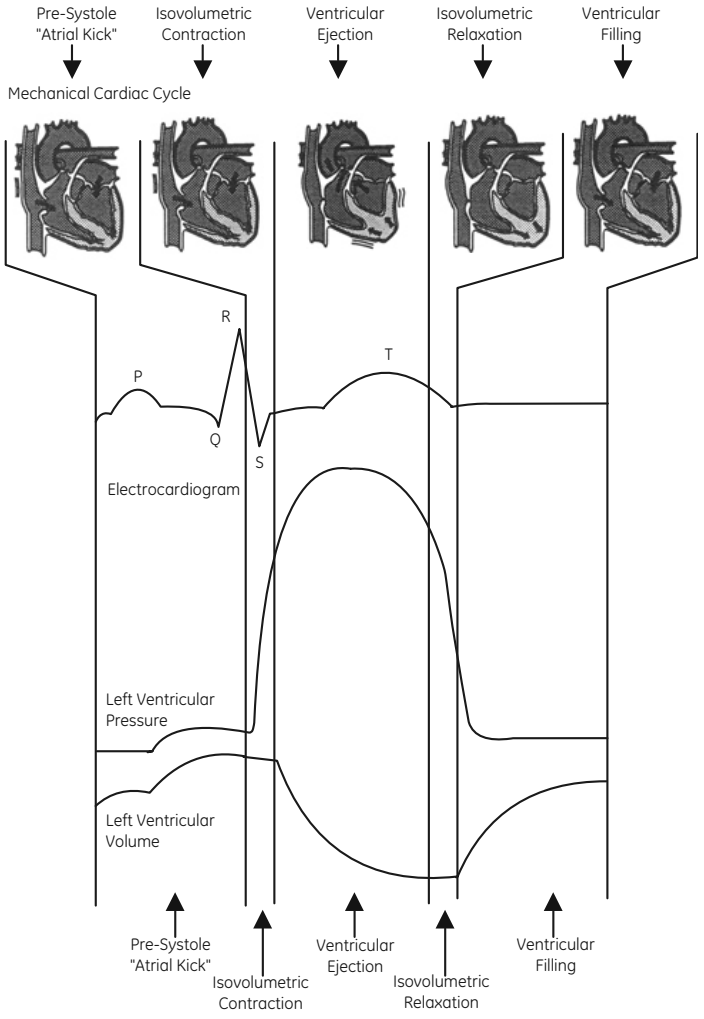


Fig 4.5 - Principles of Counterpulsation

Cardiac Cycle, Sequence of Normal Electrical Conduction [168]

1. Electrical activation begins with the electrical impulse of the SA node, causing the atria to depolarize, represented by the **P wave**.
2. Electrical impulses spread through the atria reaching the AV node (the P wave represents right and Left atrial depolarization).
3. Electrical activation is delayed at the AV node. This is represented by the PR segment.
4. Electrical activity picks up speed through the Bundle of His, right and left bundle branches, and Purkinje fibers, entering the ventricular muscle leading up to ventricular depolarization - the PR interval.
5. Ventricular muscle recovery (repolarization) occurs and produces the **ST segment** and **T wave** on the ECG.
6. Purkinje fiber repolarizarion produces a **U wave**, not usually seen.

Cardiac Index (CI) [231]

Cardiac Index (CI) is the **Cardiac Output** (CO) normalized to body size, or **Body Surface Area** (BSA). It is a more precise indicator of cardiac performance than **cardiac output**. The unit for CI is L/min/m^2 and the typical range is 2.5-3.5 L/min/m^2.

$$CI = \frac{CO}{BSA}$$

Cardiac Output (CO) [231]

The volume of blood pumped by the heart per unit of time. It is the product of the Stroke Volume (SV) and the heart rate. It is a general indicator of cardiac performance. Typical units are liters per minute (L/min). Typical range of values is approximately 4-7L/min in adults.

$$CO = SV \times HR$$

Cardiogenic Shock [234]

An abnormal condition characterized by critically low **cardiac output** in conjunction with acute **myocardial infarction** and **congestive heart failure**.

Cardiograph

See **Electrocardiograph**.

Cardiogram

See **Electrocardiogram**.

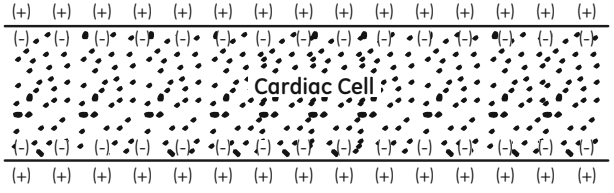
Cardiopulmonary Resuscitation (CPR) [234]

A basic emergency procedure for life support consisting of artificial respiration and manual cardiac massage. It is used in cases of **cardiac arrest** to establish effective circulation and ventilation in order to prevent irreversible cerebral damage resulting from **anoxia**.

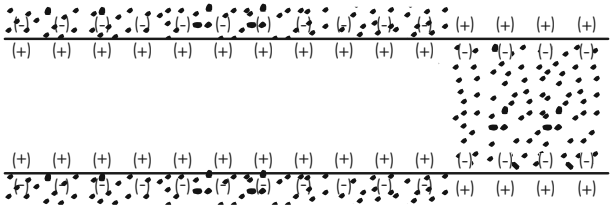
Cellular Activity, Three Phases [160]

- *Polarized State* (cell at rest) - Intracellular fluid considered negative.
- *Depolarization* (activation) – Cell becomes more positive.
- *Repolarization* (recovery) – Cell returns to resting level of negativity.

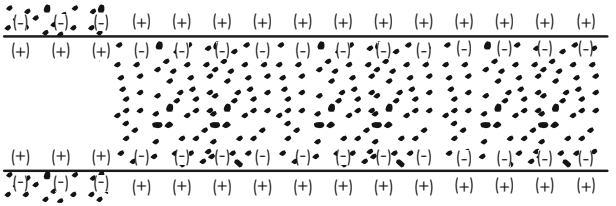
Depolarization and Repolarization



1. Resting or Polarized State



2. Depolarization, Almost Complete



3. Depolarization, Almost Complete

Fig 4.6 – Cellular Activity

Central Venous Pressure (CVP) [234]

The Central Venous Pressure (CVP) is the blood pressure in the large veins of the body, as distinguished from peripheral venous pressure in an extremity.

CI

See **Cardiac Index**.

Circulatory System [186]

The cardiac circulatory system can be divided into two halves. The right half pumps blood through the lungs, where blood is oxygenated. This half is called the pulmonary circulatory system. The left half pumps oxygenated blood and nutrients to cells throughout the body, and is called the systemic circulatory system.

CO

See **Cardiac Output**.

Conductivity [168]

The ability to transmit an impulse.

Congestive Heart Failure (CHF) [234]

An abnormal condition that reflects impaired cardiac pumping, caused by myocardial infarction, ischemic heart disease, or cardiomyopathy.

Contractility [168]
The ability to respond with pumping action.

Coronary Heart Disease [172]
Disease of the heart due to obstruction of the arteries supplying blood to the **myocardium**.

Counterpulsation [235]
Alteration of arterial pressure and volume in synchrony with the mechanical cardiac cycle. It is achieved by inflation and deflation of an intra-aortic balloon during diastole and systole, respectively.

CPR
See **Cardiopulmonary Resuscitation**.

CVP
See **Central Venous Pressure**.

Depolarization [168]
The process by which the inside of a cell becomes more positive than the outside. In the heart, the **SA node** normally controls this process that results in contraction of the heart.

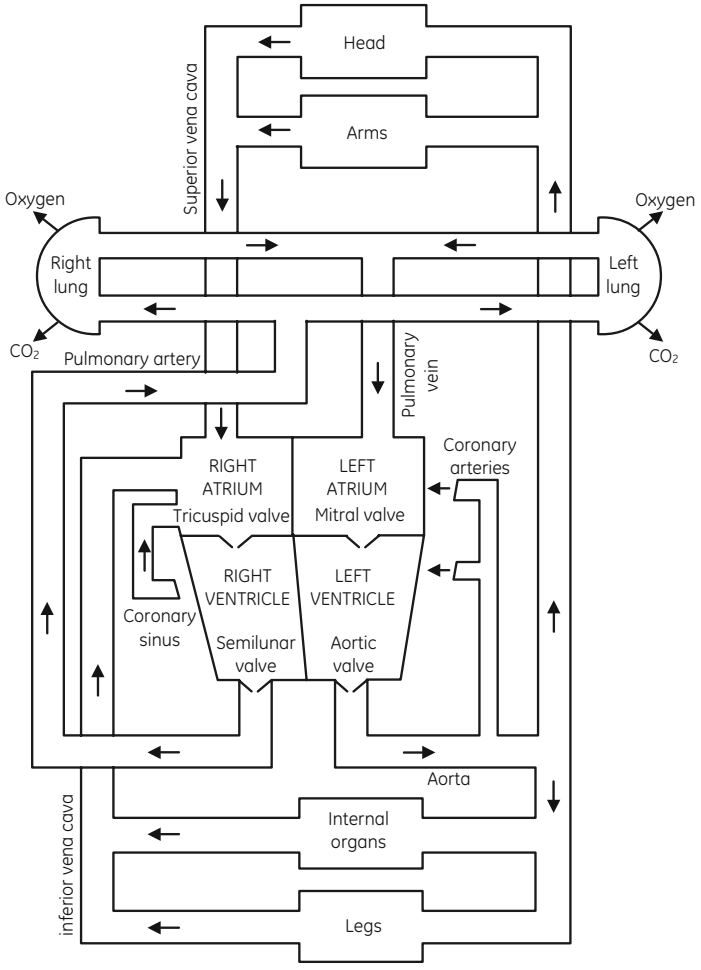


Fig 4.7 – Cardiovascular Circulation

Diastole [234]
Diastole is the period of time between contractions of the **atria** or **ventricles** during which blood enters the relaxed chambers from the **systemic circulation** and the lungs.

Diastolic Blood Pressure [234]
Diastolic blood pressure is the minimum level of blood pressure measured between contractions of the heart.

Diastolic pressures for an individual may vary with age, sex, body weight, emotional state, and other factors.

Dichrotic Notch [234]

A phenomenon observed on the downstroke of the arterial pressure waveform. It represents closure of the **aortic valve** at the onset of ventricular diastole.

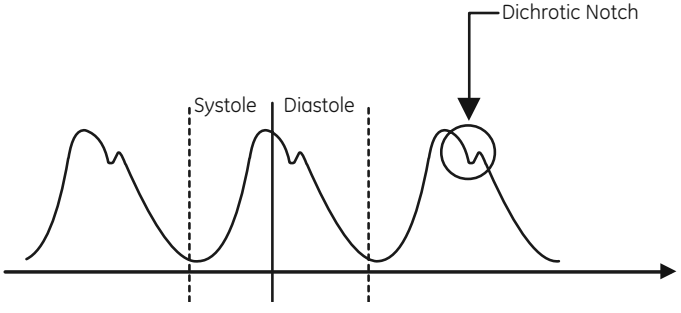


Fig 4.8 – Dichrotic Notch

Disrhythmia

See **Arrythmia**.

Dye Dilution [232]

Concentration of injected dye, plotted as a function of time, gives blood flow. It is sometimes called tracer technique.

ECG

See **Electrocardiogram**.

ECG Complex Intervals [168, 172]

- **PR Interval** - Beginning of the P wave to the beginning of the QRS complex. Normal PR interval is 0.12 to 0.20 sec.
- **QRS Interval** - The width of the QRS complex. The normal interval of the QRS complex is up to 0.1 sec.
- **QT Interval** - Onset of the QRS complex to the end of the T wave. Normal limits are a variable of heart rate.

ECG, Components of the Normal (Anatomy) [168]

- **P Wave** - Electrical forces of the atrial muscle depolarization.
- **QRS Complex** - Ventricular depolarization.
- **ST-T Wave** - Recovery (repolarization) of ventricular muscle cells.

ECG Frequency Content [164]

ECG signals contain a frequency content from 0.05 to 100 Hz.

ECG Frequency Response (Monitors) [108]

With an input amplitude of 1m V p-p and an input frequency and waveform of 0.67 to 40 Hz, siosoidal, the relative output response (in mm) should be 0.67 to 40 Hz, bandwidth (3dB down). The upper limit: 110% relative to 5 Hz output.

ECG Frequency Response (Recorders) [108]

Diagnostic ECG recorders must be capable of responding to a frequency bandwidth of 0.67 to 100 Hz. The American Heart Association recommends a diagnostic frequency response of 0.67 to 150 Hz.

ECG, Rate and Interval Determination on Paper [168]

Time is measured on the horizontal plane. Each small square equals .04 seconds or 40 milliseconds. Each large square equals .20 seconds or 200 milliseconds. Five large squares equal 1 second or 1,000 milliseconds. Amplitude is measured on the vertical plane. Each small square equals 1 millimeter (1mm). Each large square equals 5 millimeters (5mm). Two large squares equal 1 millivolt (1mV) or 10 mm.

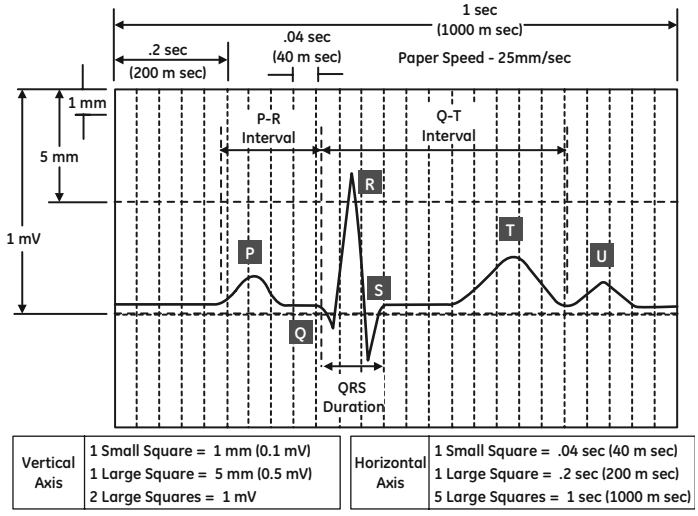


Fig 4.9 - ECG Components

ECMO

See **Extracorporeal Membrane Oxygenation (ECMO)**.

Ectopic Beat [172]

Any rhythm or beat that originates from other than the **sinoatrial node**.

EEG

See **Electroencephalograph**.

Einthoven Triangle [164, 168]

Lead I, Lead II, and Lead III, all bipolar leads, form an Einthoven triangle. This is based on Einthoven's concept of an equilateral triangle to represent the heart.

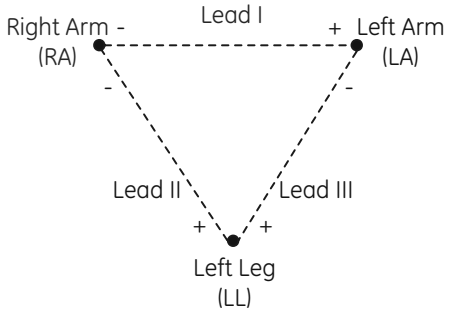


Fig 4.10 – Einthoven Triangle

EKG

See **Electrocardiogram**.

Electrocardiogram (ECG, EKG) [168]

A graphic record of the electrical activity of the heart.

Electrocardiograph [234]

A device used for recording the electrical activity of the heart.

Electroencephalograph (EEG) [186]

The recorded representation of bio-electric potentials generated by the neuronal activity of the brain.

Electromechanical Dissociation [172]

The continuation of electrical activity of the heart without the heart muscle responding.

Electromyograph (EMG) [162]

The bioelectric potential associated with muscle activity. These potentials are measured at the surface of the body near a muscle of interest or directly from the muscle using a penetrating needle electrode.

Electrode [164]

A type of sensing device that is applied at a point where a biopotential is acquired. Typical applications for electrodes are **ECG**, **EEG**, and **EMG**.

Electrode Construction [162]

Four major components of an ECG electrode are:

- Leadwire snap or tab where the leadwire attaches
- Sensing element
- Electrolyte or gel that interfaces the sensing element to the patient
- Base material with adhesive that holds the electrode in place

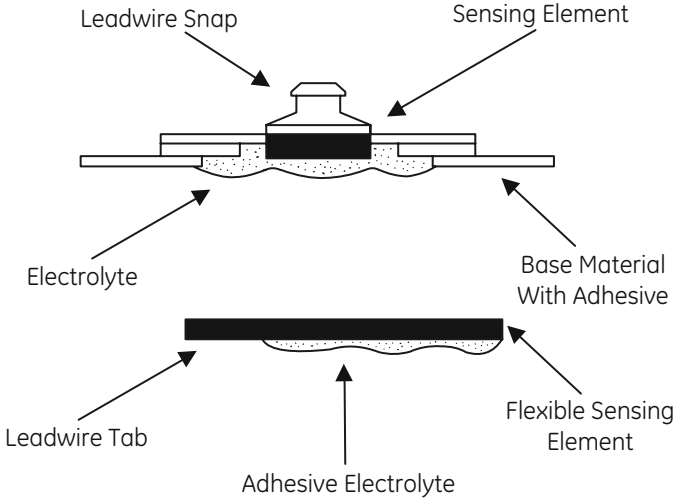


Fig 4.11 – Electrode Components

Note: In modern electrodes, one component may perform one or more of these functions. Older plate type electrodes are constructed differently.

Electrode Impedance [172]

The opposition to the flow of current caused by resistance, inductance and capacitive reactance.

Electrode Placement, Classic 12 Lead Resting [162]

Lead	Electrode Location
V1	Fourth intercostal space at the right border of the sternum
V2	Fourth intercostal space at the left border of the sternum
V3	Midway between locations V2 and V4
V4	At the mid-clavicular line in the fifth intercostal space
V5	At the anterior axillary line on the same horizontal level as V4
V6	At the mid-axillary line on the same horizontal level as V4 and V5
RA/LA	Traditionally placed anywhere on the arm; alternate placement to reduce muscle artifact, is midway between the elbow and the shoulder
RL/LL	Traditionally placed a few inches above the ankle; alternate placement to reduce muscle artifact, is on the upper leg as close to the torso as possible

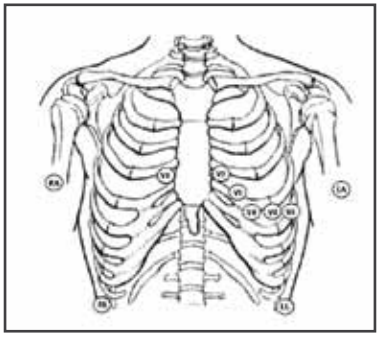


Fig 4.12 - Classic 12 Lead

Frank X, Y, and Z Leads

Anterior View

Lead	Electrode Location
V4	At the mid-clavicular line in the fifth intercostal space
V6	At the left mid-axillary line on the same horizontal level as V4
E(A2)	Mid-sternum on the same horizontal level as V4 and V6
I(A3)	At the right mid-axillary line on the same horizontal levels as V4 and V6

Note: For hi-res recording, the limb leads should be positioned as follows:

RA&LA	Right and left arm below the clavicle
RL&LL	Right and left leg on the lower abdominal quadrant

Note: For Vectorcardiograms the limb leads should be positioned according to the classical 12 lead location.

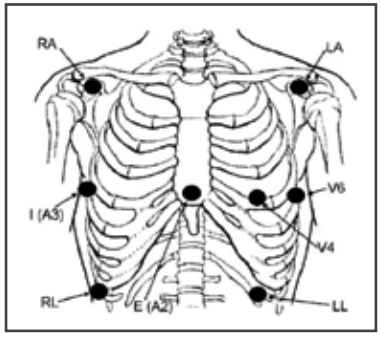


Fig 4.13 - Frank X, Y, and Z Leads – Anterior View

Posterior View

Lead	Electrode Location
H(A1)	Back of neck, avoid carotid artery, and jugular vein
M(A4)	Center of spine on the same horizontal level as V4 and V6

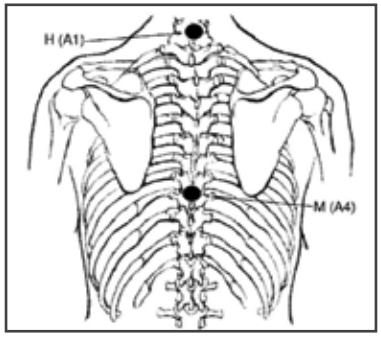


Fig 4.14 - Frank X, Y, and Z Leads – Posterior View

Bipolar-Unipolar Electrode Placement

In the bipolar-unipolar electrode configuration, one channel of ECG data will be bipolar (limb lead II) and the other will be unipolar (precordial V5). The unipolar V5 is more specific to the myocardium, however is less sensitive (useful in pinpointing a specific location in the myocardium). Unipolar V5 placement also offers a comparable lead configuration to stress testing.

Channel	Leads	Electrode Location
CH 1(-)	II(-)	Below the right clavicle, just
CH 2 (-)	V5(-)	lateral to the mid-clavicular line
CH 1(+)	II(+)	On the lower chest wall
CH 2(-)	V5(-)	
CH 2(-)	V5(+)	Fifth intercostal space, anterior axillary line
CH 2 (-)	V5(-)	Below the left clavicle, just lateral to the mid-clavicular line
Ground		On the lower right chest wall

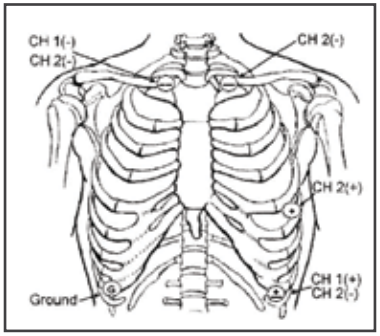


Fig 4.15 - Bipolar-Unipolar Electrode Placement

Bipolar-Bipolar Electrode Placement

The bipolar-bipolar electrode configuration provides two conventional Holter bipolar leads. The modified V5 electrode placement is more sensitive to all areas of the left ventricle, but less specific.

Channel	Leads	Electrode Location
CH 1(-)	mV5(-)	Below the right clavicle, just lateral to the mid-clavicular line
CH 1(+)	mV5(+)	Fifth intercostal space, anterior or axillary line
CH 2(-)	mV1(-)	Below the left clavicle, just lateral to the mid-clavicular line
CH 2(+)	mV1(+)	Fourth intercostal space, right sternal edge
Ground		On the lower right chest wall

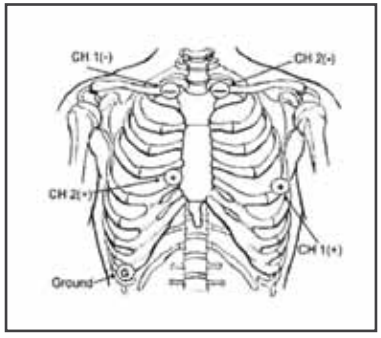


Fig 4.16 - Bipolar-Bipolar Electrode Placement

Five-Wire Cable, Modified V5 and V1 Leads

The following are the recommended electrode locations to record the modified V5 and V1 leads, with V5 recorded on channel 1 and V5 recorded on channel 2.

Channel	Leads	Electrode Location
CH 1(-)	mV5(-)	Right clavicle, just lateral to the sternum
CH 1(+)	mV5(+)	Fifth intercostal space at the left axillary line
CH 2(-)	mV1(-)	Left clavicle, just lateral to the sternum
CH 2(-)	mV1(+)	Fourth intercostal space at the right sternal edge
	Ground	Lower right chest wall

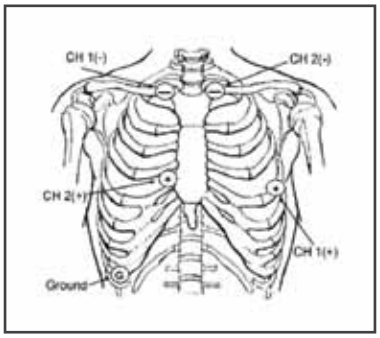


Fig 4.17 - Five-Wire Cable, Modified V5 and V1 Leads

Pacemaker detection

In the recorder, the pacemaker spike detection is done on the ECG data acquired on channel 1. Because pacemaker activity is more readily recorded in lead V5, you should always place the electrodes in locations to record lead V5 on channel 1 and lead V1 on channel 2 for a pacemaker patient.

Seven-Wire Cable, Modified V5, V1, and V3 Leads

A modified V3 lead may be helpful in identifying ST segment changes in ischemic episodes associated with the left anterior descending coronary artery. The following are the recommended electrode locations to record the modified V5, V1, and V3 leads with V5 recorded on channel 1, V1 on channel 2, and V3 on channel 3.

Channel	Leads	Electrode Location
CH 1(–)	mV5(–)	Right clavicle, just lateral to the sternum
CH 1(+)	mV5(+)	Fifth intercostal space, at the left axillary line
CH 2(–)	mV1(–)	Left clavicle, just lateral to the sternum
CH 2(+)	mV1(+)	Fourth intercostal space at the right sternal edge
CH 3(–)	mV3(–)	Mid-sternum, at the level of the clavicles

CH 3(+)	mV3(+)	Equidistant between the normal locations for precordial leads V2 and V4
	Ground	Lower right chest wall

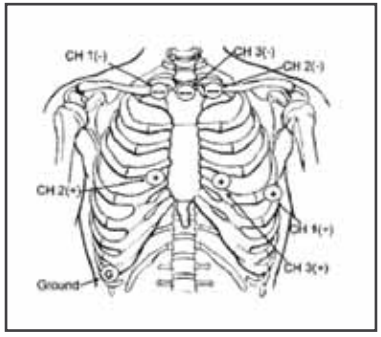


Fig 4.18 - Seven-Wire Cable, Modified V5, V1, and V3 Leads

Seven-Wire Cable, Modified V5, V1, and aVF Leads

A modified aVF lead may be helpful in identifying ST segment changes in ischemic episodes associated with the right coronary of circumflex arteries. The following are the recommended electrode locations to record the modified V5, V1, and aVF leads, with V5 recorded on channel 1, V1 on channel 2, and aVF on channel 3.

Channel	Leads	Electrode Location
CH 1(-)	mV5(-)	Right clavicle, just lateral to the sternum
CH 1(+)	mV5(+)	Fifth intercostal space at the left axillary line
CH 2(-)	mV1(-)	Left clavicle, just lateral to the sternum
CH 2(+)	mV1(+)	Fourth intercostal space at the right sternal edge
CH 3(-)	maV1(-)	Left clavicle, at the mid-clavicular line
CH 3(+)	mV1(+)	Sixth rib, at the left mid-clavicular line
	Ground	Lower right chest wall

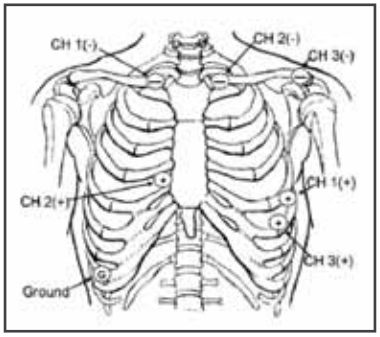


Fig 4.19 - Seven-Wire Cable, Modified V5, V1, and aVF Leads

Seven-Wire Cable, Modified V5, V1, and Z Leads

A modified Z lead may be helpful in identifying ST segment changes in ischemic episodes in the anteroposterior axis. The following are the recommended electrode locations to record the modified V5, V1, and Z leads, with V5 recorded on channel 1, V1 on channel 2, and Z on channel 3.

Channel	Leads	Electrode Location
CH 1(-)	mV5(-)	Right clavicle, just lateral to the sternum
CH 1(+)	mV5(+)	Fifth intercostal space, at the left axillary line
CH2(-)	mV1(-)	Left clavicle, just lateral to the sternum
CH2(+)	mV1(+)	Fourth intercostal space at the right sternal edge
CH3(-)	Z(-)	Mid-sternum, at the level of the clavicles
CH3(+)	Z(+)	Equidistant between the normal locations for precordial leads V2 and V4
	Ground	Lower right chest wall

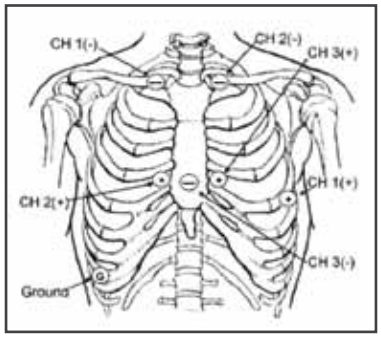


Fig 4.20 - Seven-Wire Cable, Modified V5, V1, and Z Leads

Modified Mason-Likar Electrode Placement

RA and LA electrodes should be placed just below the right and left clavicle.

RL and LL electrodes should be placed on the lower edge of the rib cage, or at the level of the umbilicus at the mid-clavicular line.

Lead	Electrode Location
V1	Fourth intercostal space at the right border of the sternum
V2	Fourth intercostal space at the left border of the sternum
V3	Midway between locations V2 and V4
V4	At the mid-clavicular line in the fifth intercostal space
V5	At the anterior axillary line on the same horizontal level as V4
V6	At the mid- axillary line on the same horizontal level as V4 and V5

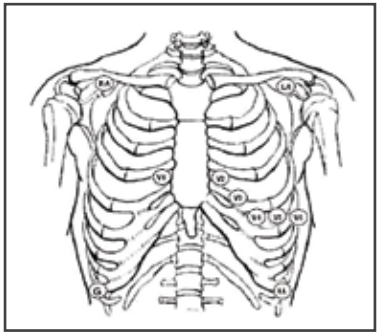


Fig 4.21 - Modified Mason-Likar Electrode Placement

Classic Bipolar Lead Placement

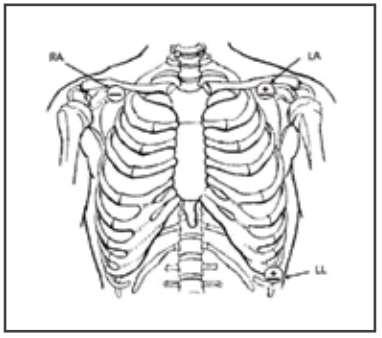


Fig 4.22 - Bipolar Lead Placement

Lead		Electrode Location
I	RA(-)	Below the right clavicle
	LA(+)	Below the left clavicle
	LL(Ref.)	To reduce artifact place on upper leg or lower rib cage
II	RA(-)	Below the right clavicle
	LL(+)	To reduce artifact place on upper leg or lower rib cage
	LA(Ref.)	Below the left clavicle
III	LA(-)	Below the left clavicle
	LL(+)	To reduce artifact place on upper leg or lower rib cage
	RA(Ref.)	Below the right clavicle

Electrophysiological Properties of the Cardiac Cell [162]
Automaticity – The ability to initiate an impulse
Excitability – The ability to respond to an impulse
Conductivity – The ability to transmit an impulse
Contractility – Ability to respond with pumping action

Embolism [234]
An abnormal circulatory condition in which an **embolus** travels through the bloodstream and becomes lodged in a blood vessel.

Embolus [234]
A foreign object, a quantity of air or gas, a bit of tissue or tumor, or a piece of **thrombus** that circulates in the blood stream until it becomes lodged in a vessel.

EMG
See **Electromyograph**.

Endocardium [234]
The lining of the heart chambers, containing small blood vessels and a few bundles of smooth muscle.

Epicardium [164]
Outer layer of the heart muscle.

Excitability (Cells) [168]
Ability to respond to an impulse.

Extracorporeal Membrane Oxygenation (ECMO) [234]
ECMO utilizes a device that oxygenates the blood of a patient outside the body through an artificial membrane and returns the blood to the patient's circulatory system. It may be used to provide oxygenation for a patient with severe lung disease or a severely impaired respiratory system.

Fibrillation [172]
The irregular, disorganized electrical activity of atria or ventricles. See **atrial fibrillation** and **ventricular fibrillation**.

Fick Principle [234]
A method for indirect measurement of **cardiac output** based on the law of conservation of mass. The amount of oxygen uptake of each unit of blood as it passes through the lungs is equal to the oxygen concentration difference between arterial and mixed venous blood. Cardiac output is calculated by measuring the uptake of oxygen for a given period of time, and dividing it by the difference in oxygen saturation of arterial and mixed venous blood samples.

Frank X Y Z Leads [172]
A lead configuration used to form three mutually perpendicular (orthogonal) leads – X, Y, Z. The leads can be paired.

His Bundle
See **Bundle of His**.

Heart Rate [234]
The pulse calculated by the number of QRS complexes or contractions of the ventricles per minute.

High-Frequency Late Potentials [192]
These appear to arise from late conducting regions produced secondary to **myocardial infarction**. They are usually associated with occurrence of ventricular arrhythmia, in particular, tachycardia or fibrillation.

High-Resolution Late Potentials [192]
A signal averaging technique performed to reduce background noise and artifact, allowing for visualization and analysis of high frequency, low amplitude (HFLA) information within the ECG. The specific areas of interest are signals within the terminal portion of the QRS, called **late potentials**.

Holter Monitor [172]
A portable ECG recording device used to make prolonged recordings while patients conduct their normal routines (typically 12-24 hours). The patients keep a diary of their activities. The recordings are later played back, comparing the

recordings with the diary.

Hypertrophy [172]
Referring to the enlargement of an organ (e.g., ventricular hypertrophy).

Hypertension [172]
A persistently high **systolic** or **diastolic** blood pressure. Cardiograms sometime indicate left ventricular hypertrophy.

Hypoxemia [234]
An abnormal deficiency of oxygen in the arterial blood.

Hypoxia [234]
Inadequate oxygen at the cellular level.

IAB
See **Infra-Aortic Balloon**.

IABP
See **Intra-Aortic Balloon Pump**.

ICHD Code
See **NASPE/BPEG Generic Pacemaker Mode Code**.

Impedance [172]
The opposition to flow of current caused by resistance, inductance, and capacitive reactance. Impedance is also sensitive to frequency changes, such as an ECG signal.

Infarction [234]
The development and formation of a localized area of **necrosis** in a tissue, vessel, organ, or part resulting from tissue **anoxia**, caused by an interruption in the blood supply to the area or, less frequently, by circulatory **stasis** produced by the occlusion of a vein that ordinarily carries blood away from the area.

Input Impedance (Monitors) [108]
The input impedance for ECG monitors over an effective frequency range of 0.5 to 40 Hz must be ≥2.5 megohms single ended at 10 Hz.

Input Impedance (Recorders) [108]
The input impedance for ECG recorders over an effective range of 0.5 to 100 Hz is 5-megohms differential.

Intra-Aortic Balloon (IAB) [235]
An intra-aortic balloon (IAB) is an invasive balloon used for **counterpulsation**.

Intra-Aortic Balloon Pump (IABP) [234]
A device that provides temporary cardiac assist in the management of refractory left ventricular failure, as may follow **myocardial infarction** or occur in preinfarction **angina**. The balloon is attached to a catheter inserted in the aorta, and is automatically inflated during **diastole** and deflated during **systole**.

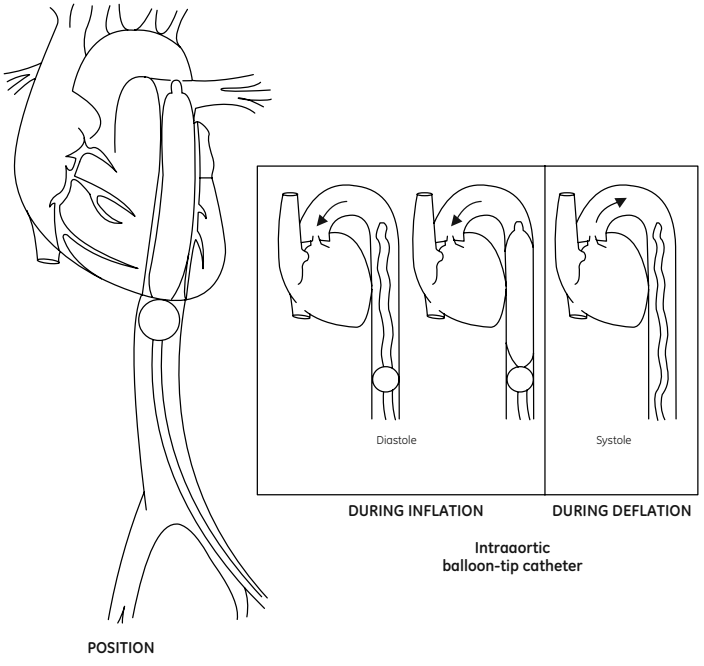


Fig 4.23 - Intra-Aortic Balloon-tip Catheter

Ischemia [234]

A decrease in the supply of oxygenated blood to a body organ or part, often marked by pain and organ dysfunction, as in ischemic heart disease. Some causes of ischemia are arterial **embolism**, **atherosclerosis**, **thrombosis**, and **vasoconstriction**.

Isoelectric Line [172]

Frequently identified as the graphic representation of an ECG when no current is flowing, the isoelectric line can be viewed as beginning at the end of the U wave to the beginning of the P wave.

J Point [172]

Described as the QRS Complex termination point and the beginning of the ST segment. The J point may have a ± amplitude.

Lead Axis [194]

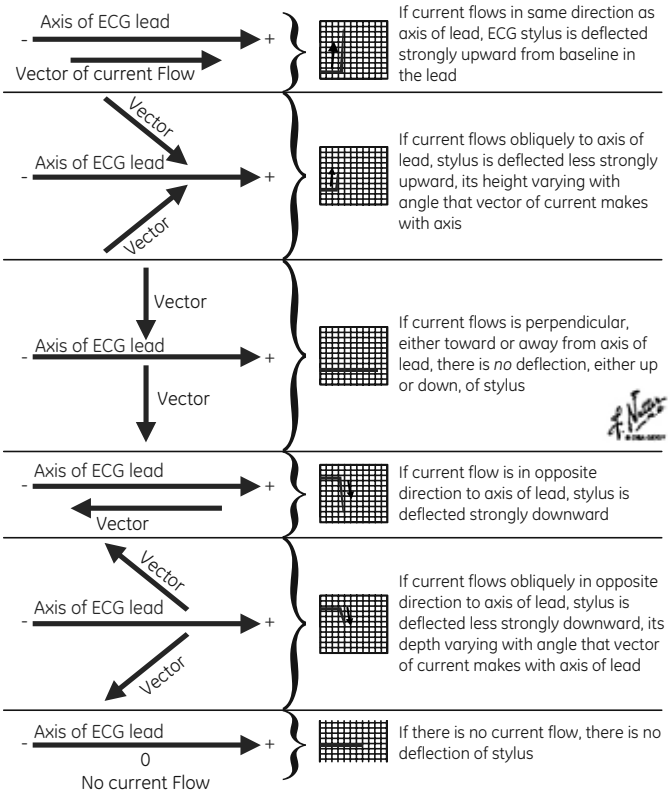

Axis of ECG lead
Vector of current Flow
If current flows in same direction as axis of lead, ECG stylus is deflected strongly upward from baseline in the lead
Vector
Axis of ECG lead
Vector
If current flows obliquely to axis of lead, stylus is deflected less strongly upward, its height varying with angle that vector of current makes with axis
Vector
Axis of ECG lead
Vector
If current flows is perpendicular, either toward or away from axis of lead, there is no deflection, either up or down, of stylus
Axis of ECG lead
Vector
If current flow is in opposite direction to axis of lead, stylus is deflected strongly downward
Vector
Axis of ECG lead
Vector
If current flows obliquely in opposite direction to axis of lead, stylus is deflected less strongly downward, its depth varying with angle that vector of current makes with axis of lead
Axis of ECG lead
0
No current Flow
If there is no current flow, there is no deflection of stylus

Fig 4.24 – Relationship of Current Flow (Depolarization and Repolarization Vectors) to Lead Axis and Consequent Electrocardiographic Deflection

Leads, Electrocardiographic With Axes [194]

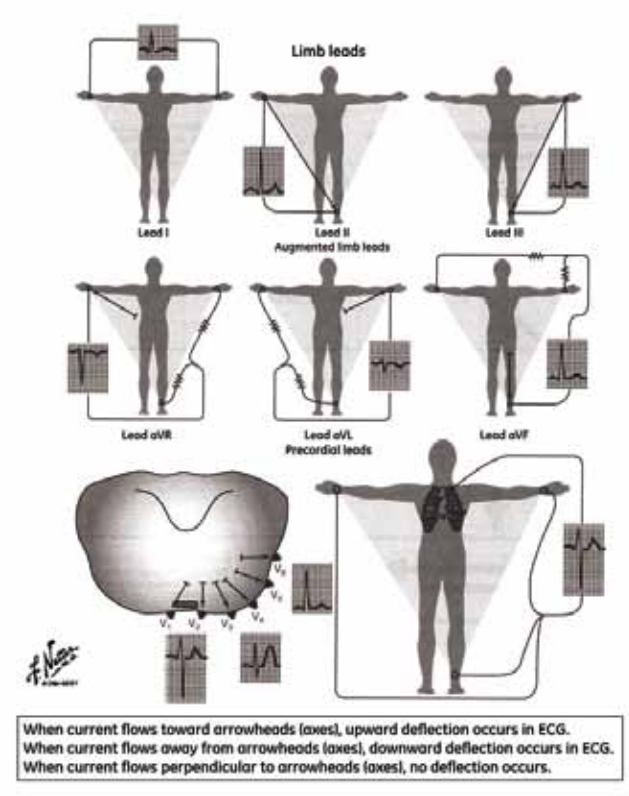

Limb leads
Lead I
Lead II
Augmented limb leads
Lead III
Lead aVR
Lead aVL
Precordial leads
Lead aVF
When current flows toward arrowheads (axes), upward deflection occurs in ECG.
When current flows away from arrowheads (axes), downward deflection occurs in ECG.
When current flows perpendicular to arrowheads (axes), no deflection occurs.

Fig 4.25 - Electrocardiographic Leads and their Axes

Korotkoff Sounds [233, 234]

The sounds heard during the taking of blood pressure using a sphygmomanometer and stethoscope. As air is released from the cuff, pressure on the brachial artery is reduced, and the blood is heard pulsing through the vessel. The cuff pressure at which the sounds are first heard is the systolic pressure. As the cuff pressure is lowered further, the sounds become louder, then dull and muffled, and finally, in most individuals they disappear, corresponding to the diastolic pressure.

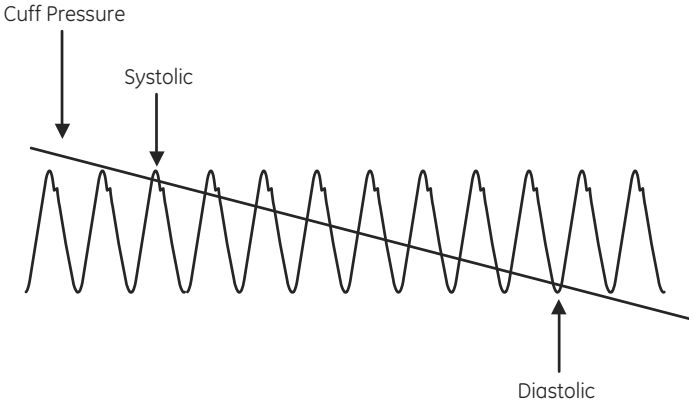


Fig 4.26 - Korotkoff Sounds

Late Potentials

See **High Frequency Late Potential**.

Leads, Frank X Y Z [172]

A lead configuration used to form three mutually perpendicular (orthogonal) leads – X, Y, Z. These leads can then be paired to form frontal, horizontal, and sagittal vectorcardiograms.

Leads, Precordial [172]

See **Precordial leads**.

Manometer [234]

A device for measuring the pressure of a fluid.

MAP

See **Mean Arterial Pressure**.

Mean Arterial Pressure (MAP, $\overline{P}_a$) [230]

The pressure in the arteries averaged over time. It may be obtained from the arterial pressure tracing by measuring the area under the curve and dividing it by the time interval.

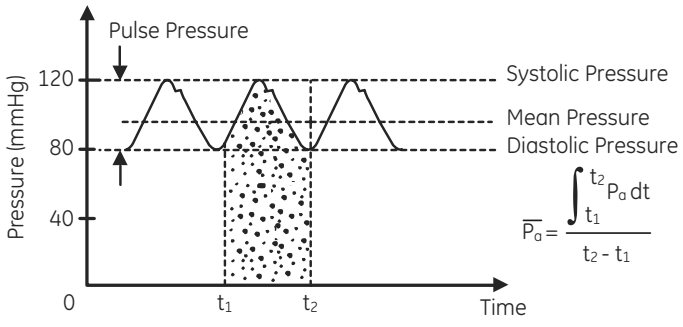


Fig 4.27 - Mean Arterial Pressure

This pressure can usually be approximated satisfactorily from the measured values of the **systolic** (P_s) and **diastolic** (P_d) pressures by

$$\overline{P_a} = P_d + \frac{1}{3}(P_s - P_d)$$

Morphology (ECG Waveforms) [178]

The study of size and shape.

Myocardial Infarction [234]

Necrosis or death of a portion of the cardiac muscle caused by obstruction in a coronary artery from either artherosclerosis or an emboli. Commonly referred to as a heart attack.

Myocardium [164]

Muscle layer of the heart located between the **pericardium** and the **endocardium**.

NASPE/BPEG Generic Pacemaker Mode Code (NBG Code) [180]

North American Society of Pacing and Electrophysiology and the British Pacing and Electrophysiology Group (NASPE/BPEG). Abbreviated as the NBG code, it is used to identify pacemaker pacing modes. Was formally known as the ICHD code. The first letter in the first position of the NBG code represents the chamber being paced, the second position represents the chamber in which the sensing occurs, and the third position represents the mode of response to the sensed signal. Chamber codes arc identified as follows: V=ventricle, A=atrium, and D=dual (atrial triggered and ventricular inhibited). Note: O is used where no other code is applicable. Positions I to III are used exclusively to describe anti-bradyarrhythmia function.

NASPE/BPEG Generic Pacemaker Code

Position I (chamber paced)

V	Ventricle
A	Atrium
D	Dual chamber (ventricle and atrium)
S	Single chamber (ventricle or atrium)
N	None

Position II (chamber sensed)

V	Ventricle
A	Atrium
D	Dual (ventricle and atrium)
S	Single (ventricle and atrium)
O	None

Position III (mode of response)

T	Triggered
I	Inhibited
D	Dual (atrial triggered and ventricular inhibited)
O	None

Position IV (programmability, rate modulation)

P	Programmable (rate and/or output)
M	Multi-programmable
C	Communicating
R	Rated modulated
O	None

Position V (antitachyarrhythmia functions)

P	Pacing (antitachyarrythmia)
S	Shock
D	Dual (pacing and shock)
O	None

NBG Code
See **NASPE/BPEG Generic Pacemaker Mode Code**.

Necrosis [234]
Localized tissue death that occurs in groups of cells in response to disease or injury.

Normal Sinus Rhythm [168]
Normal sinus rhythm is defined as the normal depolarization of both the atria and the ventricles.

Oscillometric Measurement [231]
The oscillometric technique operates on the principle that as an occluding cuff deflates from a level above **systolic pressure**, the artery walls begin to vibrate or oscillate as the blood flows turbulently through the partially occluded artery. These vibrations will be sensed in the transducer system monitoring blood pressure. The cuff pressure at the point of maximum oscillations usually corresponds to the mean **arterial pressure**. The point above mean pressure at which the oscillations begin to rapidly increase in amplitude corresponds to the **systolic pressure**. And the point below the maximum at which the oscillations begin to rapidly decrease in amplitude correlates with the **diastolic pressure**.

P Wave [168]
The first wave deflection in the cardiac cycle. The P wave represents the depolarization of both atria.

Pacemaker (External Temporary) [180]
Utilized for the temporary stimulation of heart contractions when the sinoatrial (SA) node is not functioning properly or when other conductive problems occur.

Parasympathetic Nerves
See **Autonomic Nerves**.

Pericardium [164]
A double layer of tissue that forms a sac encasing the heart. The pericardium delivers a lubricating fluid on its inside surface to reduce friction between it and the heart wall of the epicardium.

Plethysmography [234]
The measurement of changes in the sizes and volumes of extremities and organs by measuring changes in their blood volumes.

Plethysmography, Impedance [233]
Measures impedance change due to volume change caused by blood flow.

Posterior [172]
The back or back part of any structure. (See anterior for combinations that are possible with other portions of the various parts of a structure.)

PR Segment [172]
A portion of the ECG signal from the end of the P wave to the beginning of the QRS complex (whether a Q wave or an R wave).

Precordial Leads [172]
A term used to describe the chest electrodes. All precordial leads use the Wilson network as the indifferent electrode and place the exploring electrode:

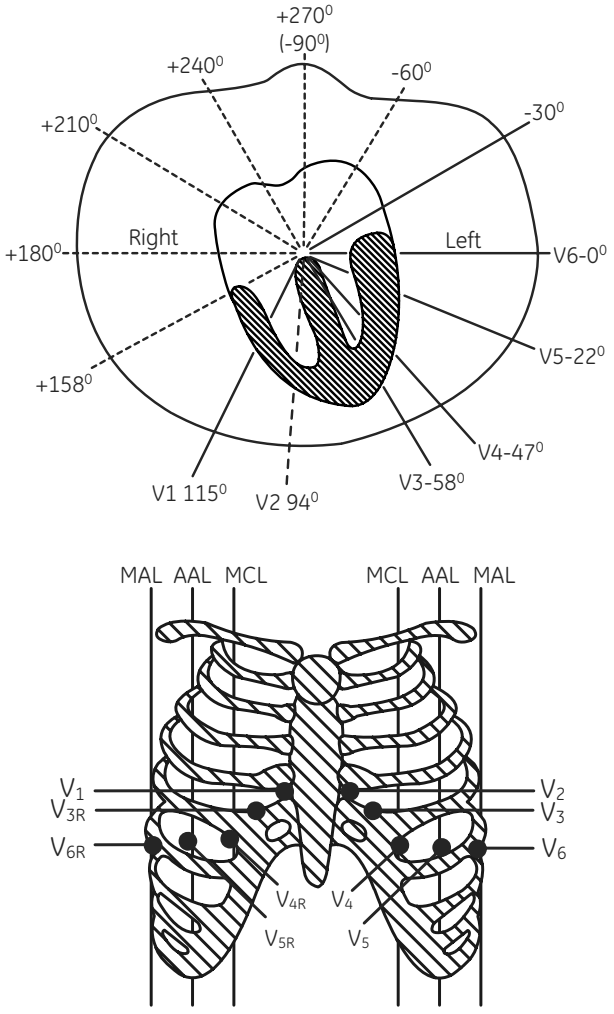


Fig 4.28 - Precordial Leads

Premature Contraction [168]

An activation (P or QRS) that occurs earlier than expected in the normal regular sequence. Also called premature depolarization.

Premature Ventricular Contraction (PVC) [168]

A cardiac impulse that is propagated from a ventricular focus before the next normal beat is due.

Pulmonary Artery [185]

The pulmonary artery carries deoxygenated blood from the right ventricle to the lungs.

Pulmonary Capillary Wedge Pressure

See **Wedge Pressure**.

Pulmonary Vascular Resistance (PVR) [235]

The resistance to right ventricular ejection, and is a clinical indicator of right ventricular **afterload**.

Pulse [234]

The regular, recurrent expansion and contraction of an artery produced by waves of pressure caused by the ejection of blood from the left ventricle of the heart as it contracts.

Pulse Rate [234]

The number of beats per minute as measured on the radial, carotid, femoral, and pedal arteries. Normally, it is the same rate as the heart beat, but pulses in various body areas may differ slightly.

Purkinje System [234]

A complex network of muscle fibers that spreads through the right and left ventricles of the heart and carries the impulses that contract those chambers almost simultaneously.

PVC

See **Premature Ventricular Contraction**.

PVR

See **Pulmonary Vascular Resistance**.

QRS Classification [168]

Q wave – initial downward (negative) component followed by upright positive component

R wave – initial upward (positive) component of the QRS complex

S wave – negative wave that occurs after the R wave

R' wave – (prime) second upward component after the R wave within a single complex

Note: All components may not be present in any given QRS complex. Certain components may have diagnostic significance.

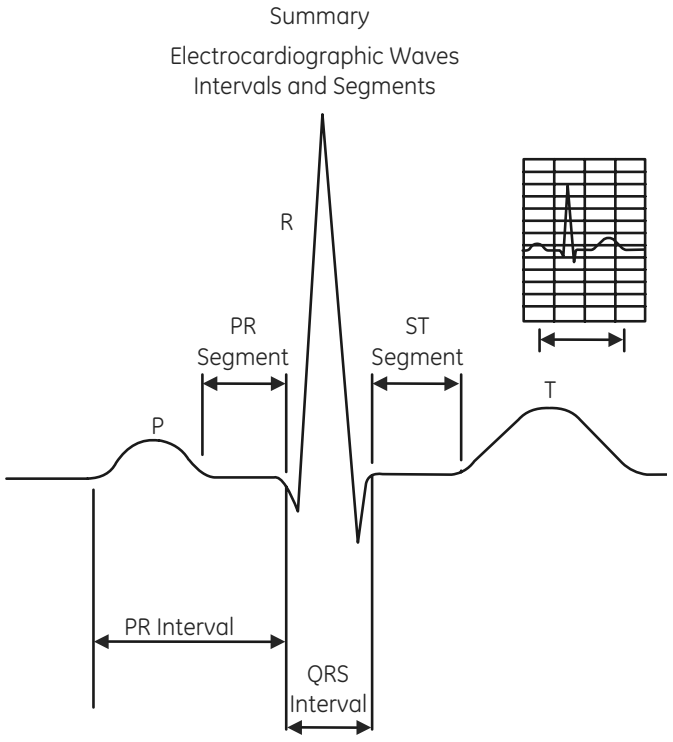


Fig 4.29 - QRS Classification

QRS Complex [168]
Reflects the depolarization of both ventricles.

QRS Interval [172]
The time (msec) from the beginning of the Q wave to the end of the S wave.

Q Wave [168]
In a lead II, the Q wave is the first negative wave before the R wave.

Radioisotope Dilution [232]
Concentration of injected radioisotope such as Xe-133, plotted as a function of time, gives blood flow; sometimes called tracer technique.

Rate and Interval Determination on ECG Paper [168]
Time is measured on the horizontal plane. Each small square equals .04 seconds or 40 milliseconds. Each large square equals .20 seconds or 200 milliseconds. Five large squares equal 1 second or 1,000 milliseconds. Amplitude is measured on the vertical plane. Each small square is equal to 1 millimeter (1mm). Each large square is equal to 5 millimeters (5mm). Two large squares are equal to 1 millivolt (1mV) or 10 mm.

Refractory Period, Absolute [168]
The period where the ventricles are depolarized and cannot be stimulated by an impulse. This period ends at the peak of the T wave.

Refractory Period, Relative [168]
The down slope of the P wave is part of the relative refractory period. An impulse received during this period can, under certain conditions, cause the ventricles to depolarize.

Repolarization [168]
The process by which cells return to their resting potential.

Rhythm [234]
The relationship of one impulse to neighboring impulses as measured in time, movements, or regularity of action.

Rhythm Regularity [172]
To determine if the rhythm is regular or irregular:
1. Place calipers on two consecutive QRS complexes.
2. Pick up left pointer then move to the following QRS complex.
3. Repeat for all QRS complexes.
4. If the difference between any R to R interval is less than 0.12 seconds, the rhythm is regular. You have determined

ventricular regularity.
5. Repeat above steps on two consecutive P waves to determine atrial regularity.

SA Node [168]
See **Sinoatrial Node**.

S Wave [168]
The negative deflection after the R wave in a Lead II complex.

Septum [234]
A septum is a partition or wall, such as the interatrial septum that separates the atria of the heart.

Sinoatrial Node [172]
A dense network of specialized cells at the junction of the superior vena cava and the right atrium where spontaneous rhythmicity of the heart originates, i.e., the normal pacemaker site.

Sinus Rhythm [234]
A cardiac rhythm stimulated by the sinus (sinoatrial) node.

Sequence of the Normal Electrical Conduction of the Cardiac Cycle [168]
1. Electrical activation begins with the electrical impulses of the SA node, causing the atria to depolarize, represented by the P wave.
2. Electrical impulses spread through the atria reaching the AV node (the P wave represents right and left depolarization).
3. Electrical activation is delayed at the AV node. This is represented by the PR segment.
4. Electrical activity picks up speed through the bundle of His, right and left bundle branches, and Purkinje fibers entering the ventricular muscle leading up to ventricular depolarization (PR interval).
5. Ventricular muscle recovery (repolarization) occurs and produces the ST segment and T wave on the ECG.

Skin Impedance [164]
Skin impedance between surface electrodes varies from 0.5Ω to greater than 20kΩ, depending on how wet or dry the skin surface is.

Sodium-Potassium Pump [164]
A process within the cells by which sodium is kept outside the cell and potassium is kept inside the cell. This attributes to the cell's resting potential.

Sphygmomanometer [234]
An instrument for **indirect measurement** of blood pressure. It consists of an inflatable cuff that fits around the arm, a bulb for controlling air pressure within the cuff, and a mercury or aneroid **manometer**.

ST Segment [172]
A portion of the ECG that is determined measured from the end of the QRS complex to the beginning of the T wave.

ST Slope [172]
A calculation measured 70 to 110 msec after the R wave peak. This measurement is used in performing calculations such as the treadmill exercise score.

Stasis [234]
A disorder in which the normal flow of a fluid through a vessel of the body is slowed or halted.

Stethoscope [234]
An instrument, used in **auscultation**, consisting of two earpieces connected by means of flexible tubing to a diaphragm, which is placed against the skin of the patient's chest or back to hear heart and lung sounds.

Stroke Volume (SV) [231]
SV measures the amount of blood ejected by the left ventricle with each cardiac contraction. The typical range of stroke

volume for adults is 60-70ml.

$$SV = \frac{CO}{HR}$$

SVR
See **System Vascular Resistance**.

Sympathetic Nerves
See **Autonomic Nervous System**.

Syncopy [190]
Sudden loss of consciousness or fainting caused by a deficient blood flow to the brain. The blood flow can result from cardiac failure or disturbances, among many other causes.

System Vascular Resistance (SVR) [235]
The resistance to left ventricular ejection, and is a clinical indicator of left ventricular **afterload**.

Systole [234]
The contraction of the heart, driving the blood into the aorta and the pulmonary arteries.

Systolic Blood Pressure [234]
The pressure measured during the period of ventricular contraction (**systole**).

T Wave [168]
A positive deflected wave in a normal ECG complex, that follows the S wave and is an indicator that repolarization of both ventricles has occurred.

Tachycardia, Ventricular [168]
The ventricular rate is between 150-250 bpm. The ectopic pacemaker in the ventricles may produce runs of **PVCs**.

Three Phases of Cellular Activity [168]

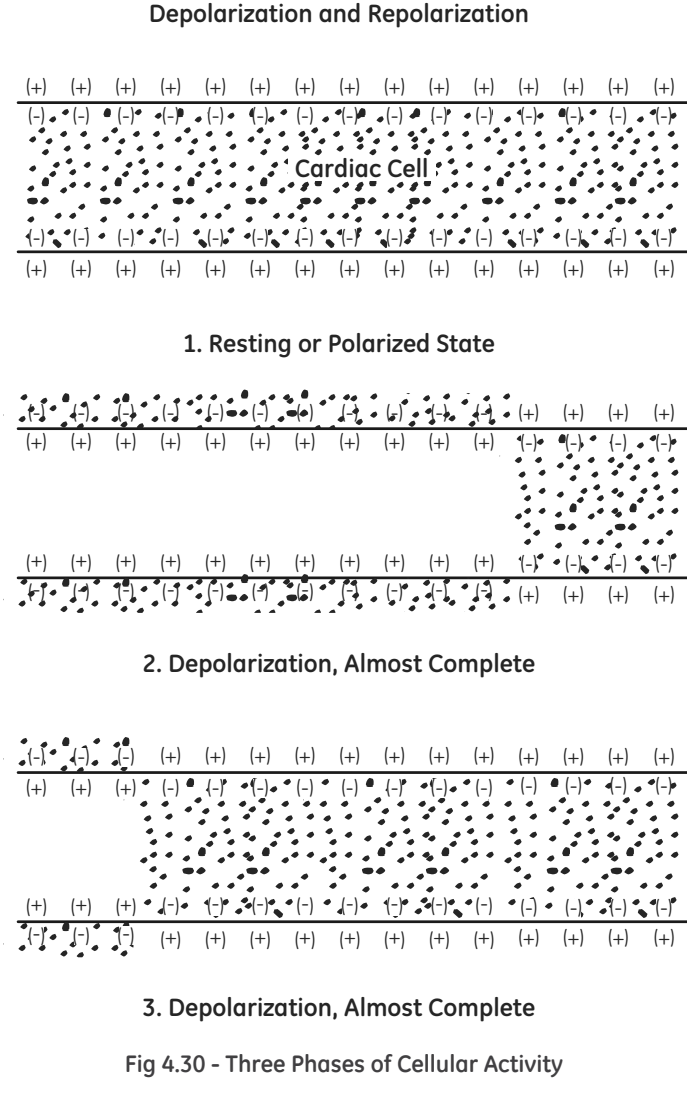


Fig 4.30 - Three Phases of Cellular Activity

Thermal Dilution [232]
Similar to **dye dilution**, a bolus (10ml) of cold (0-20°C) saline solution is injected into the right atrium; temperature of thermistor in the pulmonary artery gives blood flow data.

Thrombosis [234]
An abnormal vascular condition in which a **thrombus** develops within a blood vessel of the body.

Thrombus [234]
An aggregation of platelets, fibrin, clotting factors, and the cellular elements of the blood attached to the interior wall of a vein or artery, sometimes occluding the lumen of the vessel.

Treadmill Exercise Score [172]
Developed by Hollenberg, the treadmill exercise score allows serial qualification of the extent of coronary artery disease. It is equal to the J point amplitude and ST slope curve areas divided by duration of exercise and then multiplied by the maximum heart rate achieved.

Treadmill Tests [172]
ECG recordings during and after measured exercise on a treadmill.

U Wave [168]
A wave that sometimes occurs after the T wave and before the next P wave. This wave occurs as a result of late recovery of the ventricular **Purkinje fibers**.

Unipolar Chest Leads [164]
A lead configuration that is identified as V1 through V6. These leads measure signals at specific locations on the chest and are connected to the non-inverting input of the amplifier. The RA, LA, and LL leads are summed and connected to the inverting input of the amplifier.

Unipolar Limb Leads
See **Augmented Leads**.

Vagus Nerve
See **Autonomic Nervous System**.

Vagal Stimulation of the Heart [168]
The parasympathetic nervous supply to the heart is via the vagus nerve, which supplies the sinus node, atria, and AV junction. In this way, the autonomic nervous system can exert control on the heart rate.

Vasoconstriction [234]
A narrowing of the lumen of any blood vessel.

Vector Cardiograms [172]
A plot drawn from instantaneous spatial vectors frontally (XY), horizontally (XZ), and sagitally (YZ). The result is a series of loops representing frontal, horizontal, and sagital vectors. The **Frank orthagonal** lead system has achieved the greatest acceptance.

Ventricular Fibrillation [168]
Ineffective, multiple, disorganized contractions of the ventricles. This type of rhythm requires immediate interaction or death is imminent.

Ventricle [172]
One of two lower chambers of the heart (right ventricle and left ventricle) that receives blood from its respective atrium. The right ventricle pumps blood to the **pulmonary artery** and the left ventricle pumps blood to the **aorta**.

Wedge Pressure [234]
Wedge pressure, also pulmonary capillary wedge pressure (PCWP), is the capillary pressure in the left atrium, determined by measuring the pressure in a cardiac catheter wedged in the most distal segment of the pulmonary artery.

Wilson Network [172]

A method of forming a common terminal by connecting the three extremity lead wires through equal resistances. The resultant indifferent electrode has a zero potential, and when combined with a second or exploring electrode, becomes a unipolar lead.

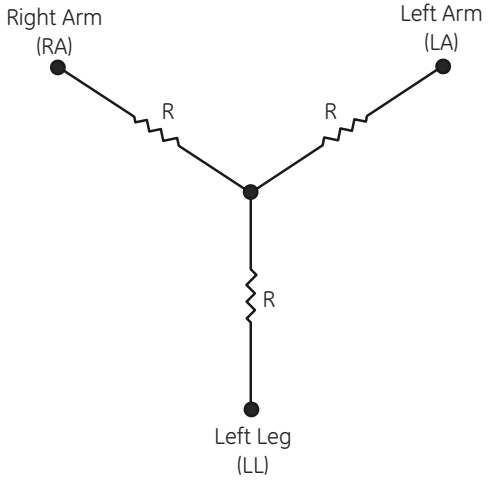


Fig 4.31 - Wilson Network

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05
Radiology and Imaging

5 – Radiology and Imaging

Absorbed Dose [234]
The energy imparted by ionizing radiation per mass of irradiated material at the place of interest. The SI unit of absorbed dose is the **gray**.

Absorption [234]
The process of absorbing radiant energy by living or non-living matter with which the radiation interacts.

ALARA [180]
An acronym that represents the radiation protection philosophy that all radiation exposure should be kept "as low as reasonably achievable."

Air Gap [180]
An air gap (increased object-film distance) can be substituted for a grid to minimize the scattered radiation reaching the image receptor.

Angstrom [180]
Unit of measurement; 1 angstrom = 10^{-10} m
Commonly used to express the wavelength of diagnostic X-ray.

Angular Momentum [179]
Physics terminology used to describe the rotational motion of a body. Angular momentum has direction (it is a vector) as well as a magnitude.

Anode (X-Ray Tube) [180]
The component of an X-ray tube that contains the positively charged stationary or rotating target, which attracts negatively charged electrons from the cathode to produce X-rays.

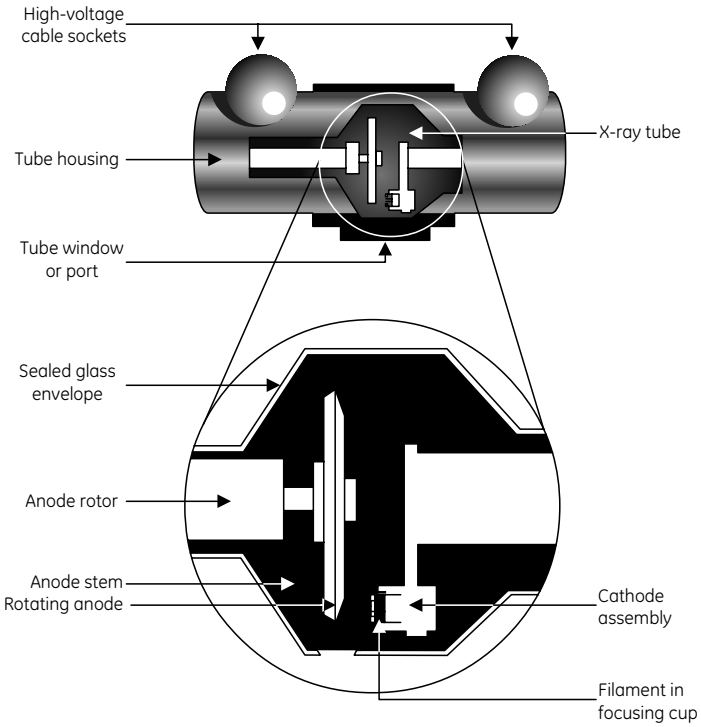

Fig 5.1 – An X-Ray Tube

Anode Heel Effect [179]
A variation in exposure rate according to the angle of emission of the **radiation** at the **focal spot**.

AP [180]
Anterior posterior – in a direction from the front to the back of a patient.

Automatic Exposure Control Systems [180]
Automatic exposure control systems, often referred to as **phototimer**, automatically terminate the X-ray **exposure**, producing a predetermined level of exposure in the image.

Automatic Film Processing [180]
A processing method in which temperature, recirculation, and replenishment are automatically controlled as film is

transported through processing solutions.

Average Gradient [180]
The slope of the straight line joining corresponding points of specific densities on the characteristic curve. Used to indicate the contrast property of a film.

BLD [180]
Beam-limiting device.
See **Variable Aperture Beam-Limiting Device**.

Background Radiation [180]
Radiation that occurs naturally in the environment.

Backscatter [180]
Radiation that is scattered backward into the path of the original beam.

Base Plus Fog [180]
The **optical density** of the film base, plus any additional density where no exposure has occurred.

Beam Limiting Devices [180]
These devices (filters, collimator, cones, or compensatory filters) allow the operator to direct and limit the X-ray beam to the area of interest.

Beam Quality [180]
This is relative to the penetrating power of an X-ray beam. Increased beam quality refers to a more penetrating beam with a high **half-value layer (HVL)**.

Blooming [180]
The change in **focal spot** characteristics that occurs when a diagnostic **X-ray tube** is operated at decreased potential and increased tube current, compared with standard test conditions (NEMA Standard 1-8-1992).

Blur [180]
A measure of the inability of all real systems to image the edge of an object with perfect fidelity. Example – Blur causes the image of a 10-millimeter micrometer slit to be more than 10 micrometers wide.

Buckey Mechanism [180]
See **Grid, Moving**.

Cassette [180]
A light-tight case, usually made of thin, low X-ray **absorption** plastic for holding X-ray film. One or two **intensifying screens** for the conversion of X-rays to visible light **photons**, mounted inside the cassette in close contact with the film.

Cathode [180]
The cathode (negative electrode) contains a **tungsten** wire (**filament**) wound in the form of a coil about 1.5mm in diameter and 10-15mm long, negatively charged component of an **X-ray tube** that repels electrons towards the anode.

Characteristic Curve [180]
A type of input-output response curve. In radiography, this curve expresses the change in optical density (output) with the change in exposure of X-ray film (input). Also called **H&D curve**, D Log curve, or sensitometric curve.

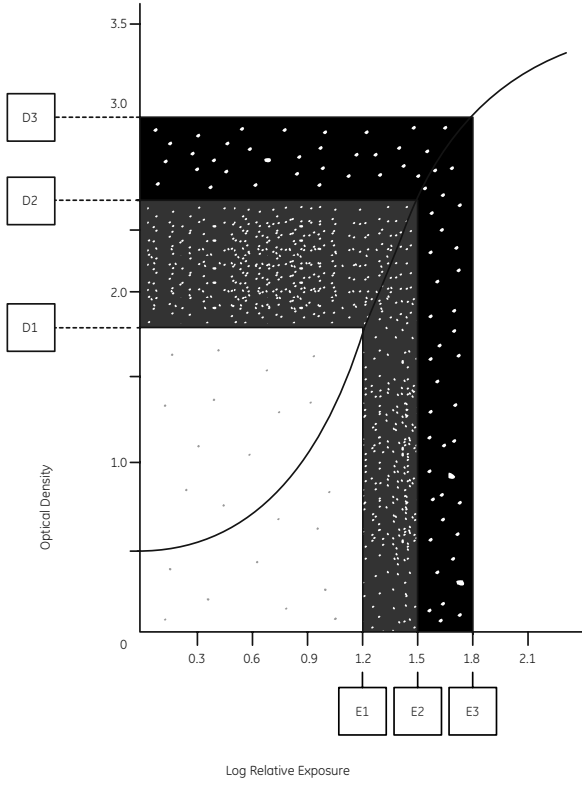

Fig 5.2 – Characteristic Curve

Cinefluorography [180]

A motion picture film recording taken from the output phosphor of an **image intensifier** (fluoroscopy).

Collimator [180]

See **Beam Limiting Devices**.

A common term for a variable-aperture, **beam-limiting device** for restricting the field of X-ray **photons** in a beam to a shape and size.

Compton Effect [179]

An incident **photon** with relative high energy strikes a free outer shell electron, ejecting it from its original orbit. The photon is deflected by the electron so that it travels in a new direction as a **scatter radiation**. The photon always retains part of its original energy. The reaction produces an ion pair, a positive atom and a negative electron, which is called a **recoil electron**.

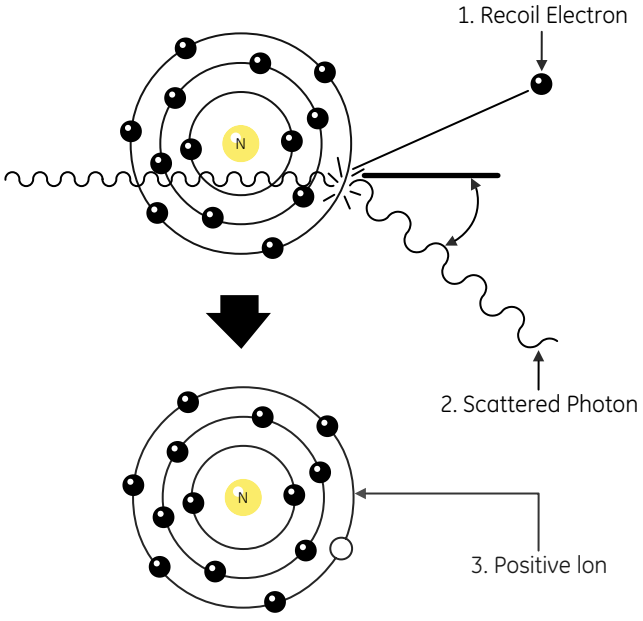

Fig 5.3 – Compton Effect

Computer Tomography [178]

An **X-ray tube** mounted in a gantry that moves in an arc around the patient during exposures. A narrow collimated beam produces a tomographic section or slice. This process is repeated nearing one-hundred thousands of times. The resulting information is then processed by a computer which reconstructs an image of the section.

Cones [180]

Metal tubes of various shapes and sizes used to restrict the **X-ray field**.

Contrast (Film) [180]

A measure of a film's property to convert input changes in

exposure (light or x-radiation) to output changes in **optical density** (film blackening).

Contrast (Radiographic) [180]
The difference in **optical density** (film blackening) between areas of interest in a **radiograph**. The combination of subject contrast and film contrast determines radiographic contrast.

Contrast (Subject) [180]
The ratio of X-ray **photon fluence** in the aerial image corresponding to different regions in the object being radiographed, due to the effects of **absorption**.

Contrast Media [180]
Substances that are introduced into body tissue to enhance inherent X-ray **absorption**; differences between body structures and the regions surrounding them. Contrast media may be **radiopaque**, such as barium, or **radiolucent**, such as air.

Crossover [180]
In reference to **dual-emulsion film**, light from the front screen that penetrates the front emulsion layer and base, causing exposure and increased blur of the black emulsion.

Cutoff (anode)
See **Anode Heel Effect**.

D Log E Curve
See **Characteristic Curve**.

Densitometer
A device consisting of a light source, an aperture, and a light sensor, used to measure **optical density**.

Density (Optical) [180]
The degree of blackening of film after **exposure** and processing.

Density (Physical)
The mass of a substance per unit volume.

Detective Quantum Efficiency (DQE) [180]
The square of the ratio of the output signal-to-noise ratio to the input signal-to-noise ratio. A measure of the efficiency with which **photons** are used for imaging.

Developer [180]
A chemical solution that converts the latent image on film to a visible image.

Digital X-Ray Imaging
See **Radiographic Digitizer**.

Distortion [180]
An inaccurately shaped shadow or aerial image of an object that occurs whenever an object is not parallel to the **image receptor**. Distortion also occurs by angulation of the X-ray tube with respect to the image receptor.

Dose [180]
A measure of the energy absorbed per unit mass, **1 gray** equals 100 rads.

Dose (Average Glandular) [180]
Generally used in breast dosimetry. Determined from values of entrance exposure in air, the X-ray beam quality **(half-value layer)**, and compressed breast thickness. Average glandular dose is the energy deposited per unit mass of glandular tissue (by far the most radiosensitive tissue in the breast) averaged over all the glandular tissue in the breast. This is also called mean glandular dose.

Dose Rate (Absorbed) [180]
The rads per minute received at a point of interest.

Double Focus (tubes) [180]
Modem **X-ray tubes** contain two **filaments**, a small and a

large, which are required to produce a small and a large **focal spot**.

Electromagnetic
[234] Pertaining to magnetism that is induced by an electric current.
[180] The range of all **electromagnetic radiations** according to their energy.

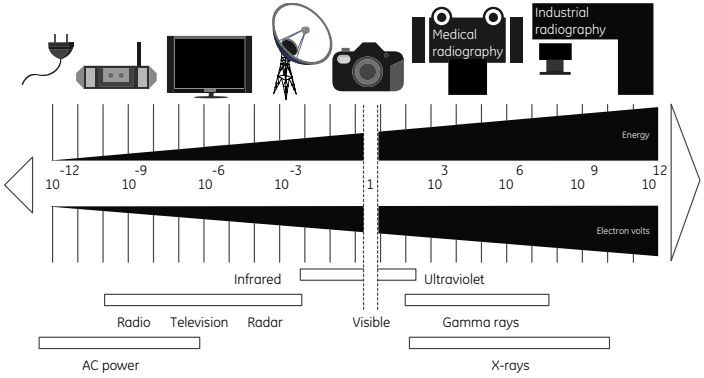

Fig 5.4 – The Electromagnetic Spectrum

Electromagnetic Radiation [234]
Every kind of electric and magnetic radiation, regarded as a continuous spectrum of energy that includes energy with the shortest wavelength (gamma rays = 0.0011 angstrom) to the longest wavelength (longwave radiowaves ≥ 1 million kilometers).

Emulsion (Film) [180]
A mixture of gelatin and silver **halide crystals** (in suspension) where **latent image** formation takes place.

Envelope (Glass) [180]
The glass housing used to encase the X-ray tube that ideally provides a perfect vacuum.

Exposure [180]
A measure of the amount of **ionization** produced in air by an **X-ray beam**, measured in mR (milliroentgen) or **R (roentgens)**.

Exposure Rate [180]
Roentgens per minute measured at a point of interest.

Extra-Focal Radiation [180]
X-radiation produced from electron interaction with metal other than the **focal spot** of the **X-ray tube**; also called off-focus **radiation**.

FFD [180]
See **Focal-Film Distance**.

Film Badge [234]
A photographic film packet sensitive to ionizing radiation, used for estimating the exposure of personnel working with X-rays and other radiographic sources.

Focal Range [180]
A range of distances, specified by **grid** manufacturers, within which a focused grid can be satisfactorily used.

FOD [180]
See **Focal-Objective Distance**.

Filtration (Added) [180]
A material or device inserted between the **X-ray tube** and the patient to preferentially absorb lower energy photons from an **X-ray beam**.

Filtration, (Inherent) [180]
The effect of all components (such as the glass wall of a tube) that filters the **X-ray beam** from its production in the target until it emerges from the **X-ray tube**.

Filtration (Total) [180]
The equivalent amount of filtering material (usually stated in millimeters of aluminum) between the **focal spot** and the object being radiographed; also, the sum of the added and

inherent filtration.

Fixer [180]
A chemical solution that both removes the unexposed and undeveloped silver **halide crystals** from the coated film emulsion, and hardens the gelatin.

Fluence [180]
In electromagnetic imaging, fluence is the number of **photons** per unit area.

Fluorescence [180]
The property of a phosphor to emit light in the visible region of the **electromagnetic spectrum** as a result of absorbing higher energy **radiation**, such as X-rays.

Focal Distance, (Grid) [180]
The distance from the point of convergence or **focal point** of X-rays to a focused grid.

Focal-Film Distance (FFD) [180]
The distance from the anode target (focus) of an X-ray tube to the radiographic film; also referred to as the target-film distance (TFD) or the source-image receptor distance (SID).

Focal-Objective Distance (FOD) [180]
The distance from the **focal spot** or **target** of an X-ray tube to the object being distance (SOD).

Focal Spot (Actual) [180]
The area of the **target** that is bombarded by the stream of electrons from the heated filament. The size of the focal spot (source of x-radiation) has a very important effect upon the formation of the X-ray image. The smaller the focal spot, the sharper the image. However, a large focal spot can tolerate more heat. Therefore, methods for obtaining a focal spot that will provide good image detail and good heat distribution must be found.

Focal Track [180]
The area that electrons strike on a rotating anode.

Focusing Cup [180]
The part of an X-ray tube's **cathode** that holds the **tungsten** filaments and shades the electron stream to a small region on the **target**.

Fog [180]
An unwanted **exposure** to the **film emulsion** from light, **radiation**, heat, or chemicals; also refers to the **optical density** on a processed **radiograph** arising from this exposure.

Gamma [180]
The slope of the straight-line portion of the **characteristic curve** that is related to film contrast.

Gamma Camera [234]
A device that uses the emission of light from a crystal struck by gamma rays to produce an image of the distribution of radioactive material in a body organ.

Gamma Rays [234]
A very high frequency **electromagnetic** emission of **photons** from certain **radioactive** elements in the course of nuclear transition or from nuclear reactions. Gamma radiation is more penetrating than alpha radiation and beta radiation, but has less ionizing power and is not deflected in electric and magnetic fields.

Generator [180]
A machine that converts AC electrical power into a waveform suitable for the production of **X-rays**.

Gradient [180]
The slope of the tangent to the characteristic curve at a given density.

Graininess [180]
The appearance of optical density fluctuations on film, caused by the random inhomogeneous distribution of silver grains as they are unevenly coated in the emulsion.

Gray [178]
A unit of **absorbed dose** or energy deposited in tissue. 1 gray equals 100 rad.

Grid [180]
A device composed of parallel or slanted lead strips and **radiolucent** spacer material, used to reduce **scattered radiation**.

Grid Cutoff [180]
A decrease in X-ray fluence caused by misalignment between the lead strips of a grid and the diverging primary beam.

Grid Ratio [180]
The relationship of the height of the lead strips in a grid to the width of its **radiolucent** spacers.

Grid Focused [180]
A grid used to reduce scattered radiation, in which lead strips are progressively tilted bilaterally to align with the diverging X-rays emanating from the focal spot.

Grid (Moving) [180]
A device comprised of a stationary grid and a mechanism for moving it that blurs the image of the lines, making them indistinguishable on the radiographic film; also referred to as a Bucky mechanism.

Grid (Parallel) [180]
A device used to reduce scattered radiation with lead strips that are parallel; also called an unfocused grid.

H & D Curve [180]
See **Characteristic Curve**.

Halite
See **Silver Halite**.

Halation [180]
A double image or halo effect that occurs when some of the exposuring light penetrates the **film emulsion** and is reflected back by the film support.

Half-Value Layer (HVL) [180]
The thickness of a given material required to reduce X-ray beam **fluence** to one-half of its original (unattenuated) value.

Heel Effect [180]
The variations in fluence across the **X-ray beam** associated with the angle of the X-ray **target**.

Image Intensifier [234]
An electronic device used to produce a fluoroscopic image with a low-radiation exposure. A beam of X-rays passing through the patient is converted in a special vacuum tube into a pattern of electrons. The electrons are accelerated and concentrated onto a small fluorescent screen, where they present a bright image. This is generally displayed on a TV monitor.

Image Processing [180]
Any operation performed to enhance or clarify an image as an aid in diagnosis.

Image Receptor [180]
The X-ray detection material (e.g., intensifying screen(s) with radiographic film) on which a latent corresponding to the aerial image is formed.

Image (Latent) [180]
The invisible changes that occur in an unprocessed image receptor and which arise from X-ray exposure.

Isotope [182]
Two or more **nuclides** that are chemically identical, yet differ in mass number, since their nuclei contain different numbers of **neutrons**.

Instantaneous Load [180]
The highest kVp and mAs value that can be used for a given length of time for a single exposure with a specific **X-ray tube**.

Intrinsic Efficiency [180]
The ratio of light energy generated in a phosphor crystal to the X-ray energy absorbed by the crystal; also called phosphor conversion efficiency.

Inverse Square Law [180]
The relationship between distance and radiation fluence in which the exposure varies inversely as the square of the distance from the source.

Ionization [180]
The process of converting atoms to ions by adding or removing electrons.

Ionization Chamber [180]
A device that produces an electric current when exposed to **ionizing radiation**.

keV [180]
Kilo electron volts.

Kilovoltage, Peak (kVp) [180]
The maximum potential difference between anode and cathode in an **X-ray tube**.

Latitude (Exposure) [180]
A measure of the tolerance allowed in the choice of exposure values required to produce the desired density range.

Latitude (Film) [180]
The capacity of film emulsion to record a wide range of exposures, resulting in the film having a lower inherent contrast. Wide-latitude film is often used for chest radiography.

Linear Accelerator [182]
Specific type of **particle accelerator**, used among other things to produce **radioisotopes** and in cancer therapy.

Linear Energy Transfer (LET) [180]
The amount of energy deposited per unit length of travel, expressed in keV per micron.

Line-Focus Principle [180]
The phenomenon that results in the difference between the size and shape of the actual **focal spot** and the effective focal spot, caused by the angle of the **target** of an **X-ray tube**.

Line Spread Function (LSF) [180]
Spatial distribution of optical density in the slit image of an **X-ray beam**.

Magnetic Resonance Imaging (MRI) [180]
A non-radiologic imaging electromagnetic process that relies on continually-spinning atomic nuclei within the body, not on X-ray generated by electron interaction.

Maximum Density [180]
The highest **optical density** that would be obtained if all the silver halide grains on a film were developed; also referred to as saturation density or D-Max.

Milliamperage (mA) [180]
A measure of electron flow.

Milliampere-Seconds (mAs) [168]
The product of the factors milliamperes and time, used to calculate changes in exposure, mAs = mA x time (sec).

MeV [180]
Million electron volts.

Modulation Transfer Function (MTF) [180]
A graphic representation of resolution capability of an imaging system or component.

Molybdenum [180]
A material used in the construction of the stem of the rotating anode. Molybdenum offers the advantage of strength, high melting point, and low thermal conductivity, which reduces heat flow from the rotating anode to the rotor and bearings.

Mottle, Quantum [180]
A form of noise that may be deigned as any random audible or visible disturbances that obscure information. This is produced by non-uniform intensity over the cross-section of an **X-ray beam** as it leaves the tube port.

Neutrons [180]
An atomic particle with no charge that is similar in mass to a proton, and is a constituent of all atomic nuclei except that of hydrogen.

Nucleus [180]
The positively charged central portion of an atom, which contains protons and neutrons.

Nuclide [180]
A species of atom characterized by the constitution of its nucleus, in particular, by the number of protons and neutrons.

Object-Film Distance (OFD) [180]
The distance from the object to the film.

Optical Density
See **Density**.

Off-Focus Radiation
See **Extra-Focal Radiation**.

Overcoat [180]
A very thin layer of clear gelatin in film, usually coated on top of the **emulsion** layer to protect it from abrasion and to provide important surface properties.

OID [180]
Object-image receptor distance.

PA [180]
Posterior anterior, a direction from the back to the front of a patient.

Parallax Effect [180]
The impression of a change in position of an object as seen on dual-emulsion film when a tube-angle technique is used.

Particle Accelerators [182]
A device used to produce a beam of fast moving, electrically charged atomic or subatomic particles.

Phantom [180]
A test object that simulates the X-ray **absorption** of various structures within the body.

Phosphor Conversion Efficiency
See **Intrinsic Efficiency**.

Phosphorescence [168]
The ability of phosphor to emit light as a result of the previous absorption of higher energy radiation.

Photomultiplier [180]
An electron device that converts varying light intensities (from a storage phosphorus screen) into varying electrical signals.

Photon [180]
A discrete bundle of energy having no mass. Photons can travel at the speed of light (186,000 mi/sec) in a vacuum.

Phototimer [180]
An electronic timing device that automatically measures and terminates the X-ray exposure to achieve a preselected density on a radiograph.

Pitting (Target) [178]
A roughing of the X-ray anode disk caused by overloading or aging. Severe pitting impairs the ability of the tube to generate X-rays.

Pixel [180]
An abbreviation for picture element.

Positive Beam Limitation (PBL) Device [180]
A beam-limiting device that automatically limits the **X-ray** beam to the size of the image receptor.

Primary Beam [180]
The beam of X-ray emitted from the focal spot that has not been scattered.

Primary Beam Leak [180]
The unattenuated portion of the X-ray beam that strikes the table or cassette, causing image undercutting.

Processing Cycle [180]
The time required for the leading edge of the film to enter and the trailing edge to exit an **automatic processor**; also called drop time.

Processor (Automatic Film) [180]
A machine that transports film through the process of developing, fixing, washing, and drying sections to produce a finished **radiograph**.

Proton [180]
An elementary particle in the atomic nucleus that has a positive charge equal to that of the electron but, with much greater mass.

QF
See **Quality Factor**.

Quality Factor [179]
The absorbed dose equivalent is equal to the absorbed dose multiplied by quality factor.

Rem = Rads x Quality Factor

Quantum [180]
A packet or bundle of electromagnetic energy.

Quantum Theory [180]
The theory that electromagnetic energy is transferred in discrete quanta or photons.

rad [180]
A unit of radiation dose. 1 gray equals 100 rads.

Radioactive [181]
The emission of radiation as a result of the disintegration of the nucleus of an atom.

Radioactive Decay [181]
The disintegration of the nucleus of an unstable **nuclide** by the spontaneous emission of charged particles, **photons**, or both.

Radiation [180]
See **X-Ray**.

Radiation Exposure [234]
A measure of the ionization produced in air by X-rays or **gamma rays**. It is the sum of the electric charges on all ions

of one sign that are produced when all electrons liberated by **photons** in a volume of air are completely stopped, divided by the mass of air in the volume element. The unit of exposure is the **roentgen**.

Radiograph [180]
An image captured on film (or other hard copy media) that is created as a result of differential **absorption** of **radiation** by objects in the **X-ray beam**.

Radiographic Digitizers [180]
Existing analog radiographs may be scanned by a film digitizer, converting the analog optical densities of the **radiograph** into a series of digital **pixel** values in an image matrix. Once in digital matrix form, the image information can benefit from the digital image processing and management features of other digital systems.

Radiolucent [180]
Relatively permeable to **X-rays** or **gamma rays**.

Radionuclide [181]
Any **radioactive** isotope that undergoes radioactive decay. These **isotopes** (e.g., strontium, iodine, cobalt, and phosphorus) are used in nuclear medicine for treatment of tumors and cancers and for nuclear imaging of internal parts of the body.

Radiopaque [180]
Relatively impermeable to X-rays or other forms of **radiation**.

Reciprocity Law [180]
A law stating that the optical density of a radiograph will be the same if the milliampere-seconds (mAs) are constant, regardless of mA.

Recoil Electron [179]
See **Compton Effect**.

Rem [179]
Unit of absorbed dose equivalent. The rem is a measure of the biological effectiveness of radiation and a unit used only in radiation protection.

1 Sievert (Sv) = 100 Rems

Roentgens (R) [234]
The quantity of χ or gamma radiation that creates 1 electrostatic unit of ions in 1 ml of air at 0 degrees C and 760 mm pressure. In radiotherapy or radiodiagnosis, the roentgen is the unit of the emitted dose. (See Rad, Rem).

Safelight [180]
A device containing a low-wattage light bulb and filter that produces visible light to which film is relatively insensitive, while still allowing one to see in the darkroom.

Saturation Density
See **Maximum Density**.

Scatter [180]
Any radiation from sources other than the **primary X-ray beam**.

Scinti-Scanner
See **Gamma Camera**.

Screen Conversion Efficiency [180]
The ratio of the light energy emitted by an intensifying screen to the X-ray energy absorbed by the screen.

Screen Speed [180]
A measure of the relative light output of various intensifying screens for a given X-ray exposure.

Sensitometer [180]
A device that exposes film to a controlled, stepped set of light exposures. It is used to evaluate a film's response to exposure.

SI [179]
The unit of absorbed dose equivalent is the sievert.

SID [180]
Source-image receptor distance.

Sievert (Sv) [179]
See **SI**.

1 Sievert (Sv) = 100 Rems

Silver Halide [180]
A compound produced by mixing a solution of silver nitrate with a solution of potassium halide. Used in photographic emulsion because of its sensitivity to light and other forms of radiation.

Slit Camera [180]
A device used in the measurement of the focal spot of an **X-ray tube**.

SOD [180]
Source-object distance.

Source-Image Receptor (SID)
See **Focal-Film Distance**.

Source-Object Distance (SOD)
See **Focal-Object Distance**.

Spatial Distribution [180]
A distribution of particles, such as photons, silver grains, or water droplets, as a function of space or distance.

SSD [180]
Source-skin distance.

Speed [180]
A measure of exposure needed to produce a given density on film.

Stepped-Wedge [180]
A device with graduated thickness that is used to demonstrate or test various degrees of **X-ray penetration**; also known as a step-wedge.

Subtraction [180]
A radiographic, photographic, or digital electronic technique in which unwanted information can be subtracted from images to enhance the visibility of the desired information. Subtraction is especially used in angiography.

Target (X-Ray Tube) [180]
The part of the anode in an **X-ray tube** toward which electrons from the **cathode** are focused and attracted, and where they interact to produce χ-radiation.

Target-Film Distance (TFD)
See **Focal-Film Distance**.

Target-Object Distance (TOD)
See **Focal-Object Distance**.

Thermonic Emission [180]
The escape of electrons from the heated **filament** in the **cathode** of an X-ray tube.

Time-Temperature Processing [180]
A technique used in manual processing that involves adjusting development time and developer temperature to produce optimum optical density and image quality for a given exposure.

Tomography [179]
A term used to describe all types of body section techniques. This is a special X-ray technique that blurs out the shadows of superimposed structures to show more clearly the principle structure being examined.

Tube Rating Charts [180]
Information provided in chart form by the manufacturer to prevent damage to an X-ray tube from excessive heat.

Tungsten (Target) [178]
Used as a target material for **X-ray tubes**, tungsten has a melting point of 3370 C. It has a high atomic number, which makes it more efficient for the production of X-rays. The rather small tungsten target must be bonded to the much larger copper portion of the anode to facilitate heat dissipation. Tungsten cannot withstand the heat of repeated **exposures**.

Undercutting [180]
Localized scattered radiation that is generated when a portion of the X-ray beam extends beyond the edge of the part being radiographed (primary beam leak).

Viewbox [180]
A device that provides a uniform field of white light for viewing the radiographic image.

Viewing Station [180]
An electronic device for the display of text and medical images in digital format.

Voxel [180]
An abbreviation for volume element, referring to the location in a patient represented by a **pixel**.

Wave [180]
A variation or disturbance that transfers energy progressively from point to point in a medium.

Workstation [180]
An electronic device for the display, manipulation, and evaluation of text and digital images.

X Rays [180]
A form of electromagnetic energy.
Characteristics:
1. X-rays can travel in a vacuum.
2. X-rays are produced when a fast stream of moving electrons undergo sudden deceleration.
3. An X-ray is an electromagnetic radiation that occurs as both waves and particles. They are classified as highly penetrating, invisible rays.
4. X-rays cannot be deflected by either electric or magnetic fields. X-rays are electrically neutral.
5. X-rays are polyenergetic or heterogeneous, thus having a wide span of energies and wavelengths. The useful energy range in radiography is about 25 to 120 KVp (maximum photon energy 25 to 120 keV).
6. Minute amounts of heat are liberated on passing through matter.
7. Ordinarily, X-ray travels in straight lines.
8. X-ray travels at the speed of light, 186,000 mi/sec in a vacuum.
9. Gases are ionized indirectly by X-ray because of their ability to remove orbital electrons from atoms.
10. X-ray causes fluorescence of certain crystals, making possible their use in fluoroscopy and in radiographic intensifying screens.
11. X-ray cannot be focused by a lens.
12. X-ray affects photographic film, producing a latent image that can be developed chemically.
13. Properties of an X-ray produce chemical and biological changes by ionization and excitation.
14. Secondary and scattered radiations are produced by X-ray.

X-Ray Tube [180]
The X-ray tube converts the electrical energy provided by the generator into an X-ray beam. This is accomplished by imposing a high voltage between the negative **cathode** and the positive **anode** of the tube. When electrons are produced at the negatively charged cathode and accelerated toward

the anode, they strike the positively charged target area of the **anode**, and produce X-rays.

Zonography [179]

A narrow-angle **tomography** employing an arc of less than 10 degrees. The process is unique in that it requires a multidirectional tube motion.

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06
Anesthesia and Respiratory Care

06 – Anesthesia and Respiratory Care

ABG [126]
Also known as **Arterial Blood Gas**. It is the measurement of partial pressure of oxygen and carbon dioxide within arterial blood.

APL Valve [124]
Also known as **Adjustable Pressure-Limiting** valve. It is a limiting valve that releases gas over an adjustable range of pressures. This valve is also referred to as a pop-off valve.

ARPV, (Ventilation) [184]
Airway pressure release.

Absorbent (Barium Hydroxide Lime) [126]
A chemical substance that removes carbon dioxide (CO_2) from the breathing circuit by chemical neutralization process which produces carbonates, water, and heat. Capacity = 27.1 liters of carbon dioxide per 100 grams of absorbent.

Absorbent (Soda Lime) [126]
A chemical substance that removes carbon dioxide from the breathing circuit by a chemical neutralization process that produces carbonates, water, and heat. Capacity = 25.1 liters of carbon dioxide per 100 grams of absorbent.

Absorber [126]
The component of a rebreathing system designed to remove carbon dioxide from patient gas.

Absorption [126]
The passage of water and/or dissolved substances into cells of the body.

Air [124]
The elastic, invisible mixture of gases (primarily nitrogen and oxygen) that may be used with medical equipment; also referred to as medical air.

Airway [126]
1. The pathway for air traveling between the atmosphere and the alveoli.
2. In anesthesia or resuscitation, a mechanical device used to keep the passage of the upper respiratory tract open for the passage of air.

Aladin Cassette
Used in new anesthesia machines to hold agent. This style of machine uses electronic vaporization instead of the mechanical vaporizers.

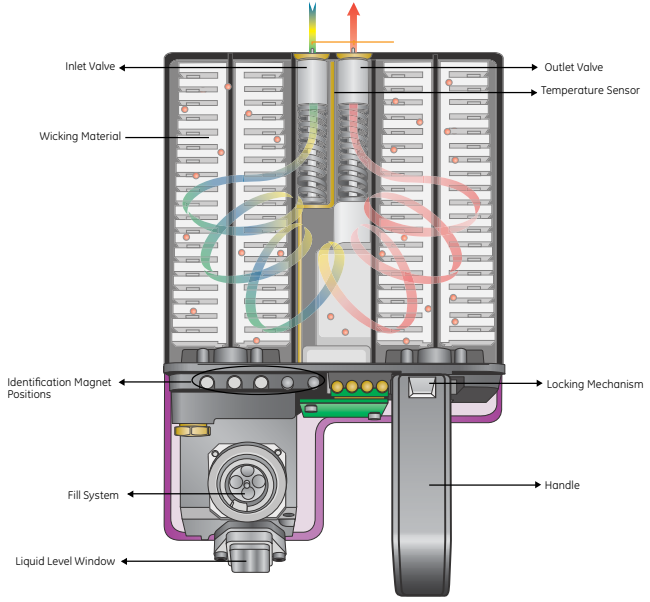


Fig 6.1 – Internal View of Aladin Cassette (top)

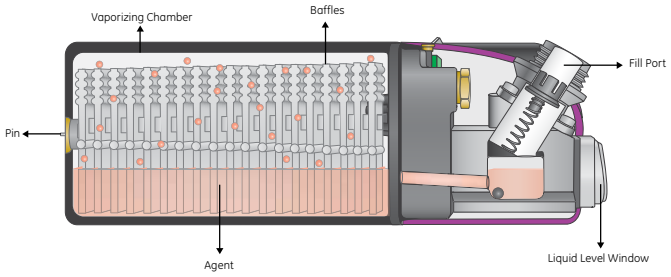


Fig 6.2 – Internal View of Aladin Cassette (side)

Alarm [132]
A warning signal that is activated when the oxygen reading reaches or exceeds the alarm limit.

Alarm Limit [132]
Oxygen reading at which the alarm is first activated.
Note: This occurs either when, a decreasing oxygen level reaches the low alarm limit, or an increasing oxygen level reaches the high alarm limit.

Alarm Set-Point [132]
Alarm limit adjustment control or display value that indicates the oxygen reading at which the alarm will be activated (the indicated alarm limit).
Note: Depending on the construction and design of the equipment, the alarm limit and the alarm set-point may differ from each other.

Alarm System [132]
Those parts of the oxygen analyzer which:
- Establish the alarm limit(s)
- Detect when the indicated oxygen level exceeds the alarm limit(s)
- Provide a warning signal when the alarm limit(s) is/are exceeded

Alveolar Pressure (PA) [126]
The air pressure in the pulmonary alveoli.

Alveolar Membrane [126]
A thin layer of tissue that serves as a partition between the air in the alveoli and the capillary blood.

Anesthetic Vapor Delivery Module Colors [130]

Anesthetic Agent	Color	Federal (594a) U.S.
Halothaned	Red	11105
Enflurane	Orange	22510
Desflurane	Blue	* NA
Not for agent	White	37875
Identification	Black	15042
Sevoflurane	Yellow	* NA
Spare	Gray	16251
Isoflurane	Purple	None

Table 6.1 - Anesthetic Agent Colors

Note: If a color is used on anesthetic vapor delivery module bottle and package labels to enhance correct identification, it is important that only the color for the appropriate agent is used.

Alveoli (Alveolus, Singular) [126]
Microscopic air sacs located at the very end of the bronchial tree, where the actual exchange of gases with the blood takes place. Normal human lungs contain approximately 300,000,000 alveoli.

Analgesia [124]
Absence of sensibility to pain; designating particularly the relief of pain without loss of consciousness.

Analgesic Agent [124]
An agent that alleviates pain without causing loss of consciousness.

Aneroid Gauge [124]
A gauge in which the pressure sensing element is an elastic diaphragm.

Anesthesia [126]
Partial or complete loss of sensation with or without loss of consciousness.

Anesthesia Machine [124]
Equipment intended for dispensing and delivering anesthetic gases and vapors into a breathing system. (**See Fig 6.3 on following page**)

Anesthesia System [124]
Any of a variety of assemblies designed to administer an anesthetic.

Anesthetic Agent Vapor [124]
The gaseous phase of an anesthetic agent that is normally a liquid at room temperature and atmospheric pressure.

Anesthetic Agent Vapor Concentration [124]
The percentage of anesthetic agent present in the total anesthetic gas mixture.

Anesthetic Gas [124]
Any gaseous substance (e.g., cyclopropane) used in producing a state of anesthesia.

Anesthetic Vaporizer [124]
A device designed to facilitate the change of an anesthetic substance from liquid to a vapor.

Anesthesia Location [124]
An area of a hospital in which it is intended to administer any anesthetic agent or drug in the course of examination or treatment. This includes operating rooms, delivery rooms, emergency rooms, induction rooms, and other areas.

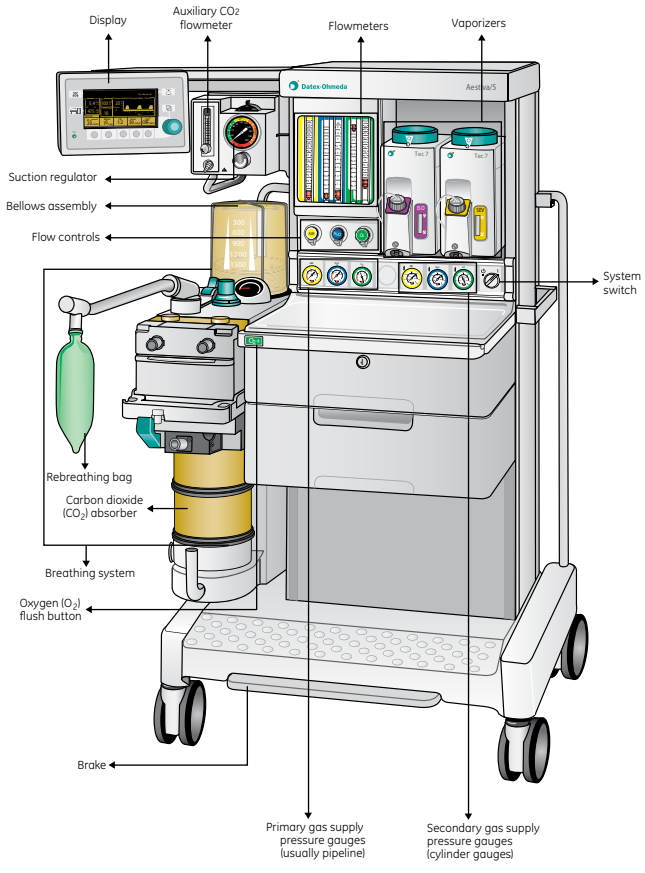


Fig 6.3 – The Anesthesia Machine Front View

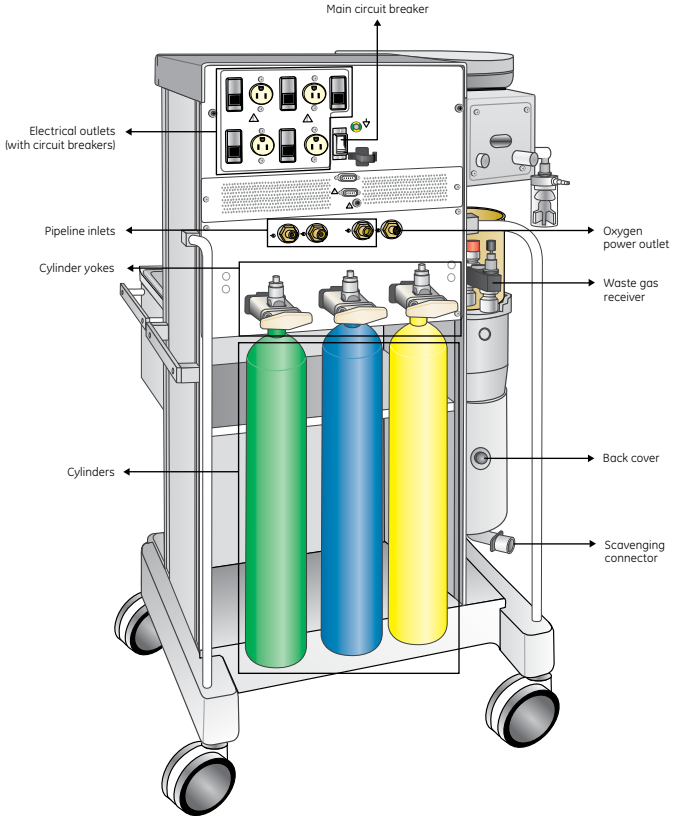


Fig 6.4 – The Anesthesia Machine Back View

The Basic Anesthesia Machine

This is the teaching model selected for understanding the basics of machine operation. Its design is traditional and lends itself to graphic representation. It incorporates all the components needed for learning the essentials.

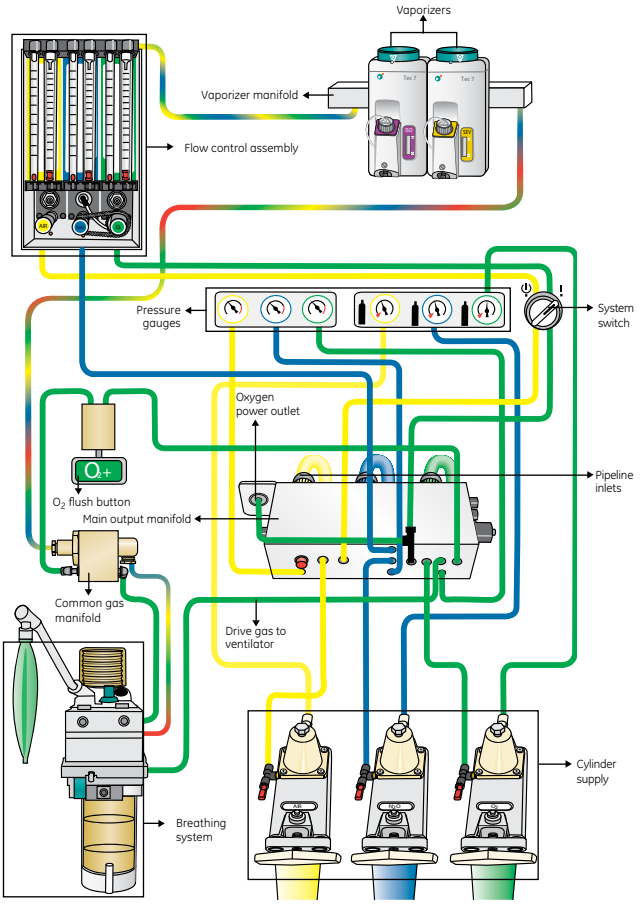


Fig 6.5 – The Anesthesia Machine – A Look Inside

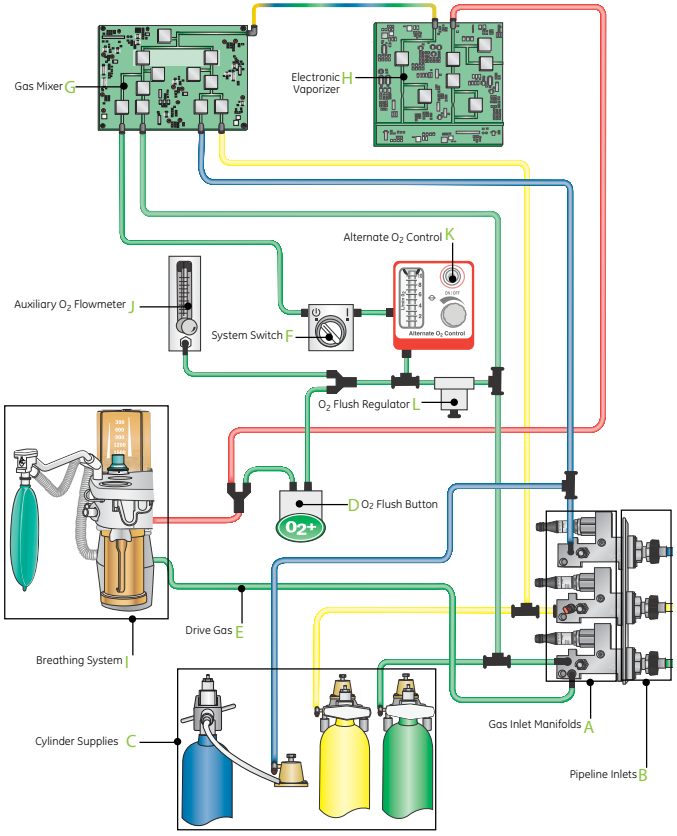


Fig 6.6 - Example of Gas Distribution Schematic

Note: See below for Gas Flow Summary of the Gas Distribution Schematic

A Gas Inlet Manifolds

As you can see from the diagram, each of the gases—nitrous oxide, oxygen and AIR—enters its respective gas inlet manifold, where the gas is distributed to other parts of the machine.

B Pipeline Inlets

Pipeline supplies of each gas enter the appropriate gas inlet manifold through the pipeline inlets.

C Cylinder Supplies

Cylinder supplies of each gas flow through tubing leading from each cylinder to its respective gas inlet manifold.

D O_2 Flush Button

Oxygen flows through the O_2 flush regulator **M**, where its pressure is reduced to 35 psi before entering the O_2 flush valve. When the O_2 flush button is pushed, the flush valve opens and supplies a high flow of O_2 to the breathing system.

E Drive Gas

The drive gas tubing has a direct connection from the gas inlet manifold to the ventilator, which uses oxygen to pneumatically power some of its components. The oxygen taking this path is called as drive gas since it helps close valves and also pushes the bellows down to force gas to the patient.

F System Switch

After passing through the alternate O_2 control **K**, oxygen continues to the system switch. When the system switch is turned ON, oxygen travels into the gas mixer **G** through the alternate O_2 inlet.

G Gas Mixer

The gas mixer has direct connections from the AIR, oxygen and nitrous oxide manifolds. As mentioned above, oxygen also enters the gas mixer through the alternate O_2 inlet after passing through the system switch.

Inside the gas mixer, selector valves open or close to allow oxygen and a balance gas (either nitrous oxide or AIR) to flow into the mixer. Flow control valves then open proportionally to allow the proper amount of oxygen and balance gas to mix together, forming the mixed gas that makes its way over to the electronic vaporizer **H**.

H Electronic Vaporizer
Mixed gas travels from the gas mixer to the vaporizer, where it picks up anesthetic agent that has entered the machine from the Aladin agent cassette. This mixture of gas (now called "common gas") is routed down to the breathing system **I**.

I Breathing System
Gas entering the breathing system is then delivered to the patient either manually (by squeezing the rebreathing bag) or mechanically by the ventilator.

J Auxiliary O_2 Flowmeter
Before entering this optional component, oxygen flows through the O_2 flush regulator **L**, where its pressure is reduced to 35 psi . Oxygen can then be delivered to the patient through a nasal cannula connected directly to the flowmeter.

K Alternate O_2 Control
This component has a direct connection from the O_2 flush regulator. In the event of a gas mixer failure (or if the alternate O_2 is manually turned on), a valve in the gas mixer opens. This allows delivery of the alternate O_2 flow through the disabled gas mixer to the electronic vaporizer **H**, as long as the system switch is in the ON position. The clinician may still deliver anesthetic agent along with the alternate O_2 flow, provided he can view the screen and reset the agent level.

L O_2 Flush Regulator
Oxygen from the pipeline inlet manifold passes through this component before reaching the O_2 flush valve, the auxiliary O_2 flowmeter, and the alternate O_2 control. The O_2 flush regulator reduces the oxygen pressure from pipeline pressure 45-55 psi) to 35 psi.

APL Valve (Adjustable Pressure Limiter Valve) [126]
This valve is located downstream of the PEEP valve on the absorber mounting block that releases excess gas to the scavenger system while in the manual (bag) mode of ventilation.

Apnea [126]
Cessation of respiration.

ARDS [126]
Adult Respiratory Distress Syndrome.

Arterial Blood Gas [126]
The measurement of partial pressure of oxygen and carbon dioxide within arterial blood.

Arterial-to-Alveolar Gradient [126]
Refers to pressure difference of carbon dioxide or oxygen.

Arterial Pressure [126]
The pressure within the arteries.

ASA [126]
American Society of Anesthesiologists.

AV-E85 [126]
Electronic anesthesia ventilator (North American Dragger).

Bain Circuit [126]
A breathing circuit composed of two tubes, with one tube situated inside the other. In a Bain circuit, fresh gas continually flows towards the patient through the inner tube; during exhalation, the respired gas flows away from the patient through the outer tube. This breathing circuit is popular for use with children.

Barometric Pressure [126]
The pressure of air registered on a barometer; standard barometric pressure at sea level is 760 mmHg (29.92 inHg).

Barotrauma [126]
A rupture of or physical injury to the lungs as a result of exposure to excessively high pressure.

Bernoulli's Principle [184]
Describes the flow of fluid through a tube. As the forward velocity of a gas increases, its lateral pressure decreases with a corresponding increase in forward pressure. The motion (flow) of the gas causes a transfer in the force that the molecules exert.

Boiling Point [128]
The saturated pressure exerted by the vapor phase of a potent volatile agent depends only on the volatile agent and the ambient temperature. The temperature at which vapor pressure becomes equal to ambient (atmospheric) pressure and at which all of liquid agent changes to the vapor phase is the liquid's boiling point.

Bourdon Gauge [126]
Gauge used to measure high-pressure gases. It consists of a hollow, curved tube. As gas pressure increases inside the tube, the tube begins to straighten. The movement is translated into a pressure reading by way of a geared device attached to a needle on the face of the gauge.

Boyle's Law [184]
If the temperature and mass remain constant, the volume of the gas varies inversely with its pressure.

$$P1 * V1 = P2 * V2$$

P1 = Initial Pressure, V1 = Initial Volume
P2 = Final Pressure, V2 = Final Volume

BPM or bpm [126]
Breaths per minute.

Breathing Attachments [132]
Components intended to make up or complete an anesthetic breathing system.

Breathing Rags [128]
Serve as a reservoir for anesthetic gases or oxygen from which the patient can inspire. They provide the means for a visual assessment of the existence and rough estimate of the volume ventilation, and they serve as a means for manual ventilation.

Breathing System (Patient Circuit) [124]
The gas pathway in direct connection with the patient through which intermittent or reciprocating gas flow occurs and into which a mixture of a controlled composition may be dispensed.

Breathing System - Semi-Closed [124]
This system allows some of the expired gases to pass to atmosphere; the remainder mixes with the fresh gases and is rebreathed. A CO_2 absorber is used in this system.

Breathing System - Closed [124]
This system allows complete rebreathing of expired gas. A CO_2 absorber is used in this system.

Breathing System - Open [124]
This system is designed so the patient inhales only the anesthetic mixtures delivered by the anesthesia machine. No CO_2 absorber is used, and rebreathing is minimal.

Bubble-Through Vaporizer [124]
This refers to a specific design of vaporizer, e.g., Veritrol™ or Copper Kettle, in which the carrier gas is bubbled through the liquid anesthetic agent.

CMV (Ventilation) [184]
Continuous mandatory ventilation.

COPD [184]
Chronic obstructive pulmonary disease.

CPAP (Ventilation) [184]
Constant positive airway pressure; patient breathing spontaneously at an elevated baseline pressure.

CPPB
See **CPAP**.

Capillaries [126]
Minute blood vessels that form the connection between small arteries (arterioles) and veins. It is at the capillary level that exchange takes place between the blood and cells, or the blood and the alveoli.

Cardiac Output [126]
The volume of blood pumped by the heart per minute. In anesthesia, cardiac output is usually monitored by a Swan-Ganz catheter as blood passes from the right ventricle into the pulmonary system.

$$CO = HR\ (bpm) * Stroke\ Volume$$

Caution Signal [132]
Indication meaning that caution or prompt action is required. Note: Examples of such a condition are a change from mains to battery power in a mains-operated device, or the battery test mode activated.

Central Venous Pressure [126]
The pressure of blood in the right atrium of the heart.

Charles' Law [184]
If the pressure and mass remain constant, the volume of a gas varies directly with the changes in absolute (Kelvin) temperature.

$$V_1/T_1 = V_2/T_2$$

Where V_1 and T_1 are the initial volume and temperature and V_2 and T_2 are the final volume and temperature.

Check Valve [126]
Allows gas to flow in one direction only.

Calibrated Vaporizer [124]
This refers to an agent specific vaporizer used to introduce anesthetic agent into the gas delivered from the anesthesia machine.

Carbon Dioxide (CO_2) [124]
An odorless, colorless gas resulting from the oxidation of carbon. It is formed in the tissues and eliminated by the lungs.

Central Vacuum System [128]
Certain standards exist for the central vacuum source and vacuum piping system. Canadian standards are considered the most complete and current. Major operating rooms must have enough suction to move 99L of air per minute. Small operating rooms (minor rooms) and locations outside the OR require only 57 or 28 L/min. Factors such as normal wall suction (-7 psig), total flow of the system, and the length of the longest run of pipe must be considered in order to maintain adequate suction. There must be two independent vacuum pumps, each one capable of handling the peak load alone. An automatic switching device distributes the load under normal conditions and shifts automatically if one unit fails. Emergency power connections are essential. The pumps must be located away from oxygen and nitrous oxide storage. There must be traps to collect and safely dispose of any solid or liquid contaminates introduced into the system, and the system piping must not be exposed to low temperatures (to prevent condensation). The type and location of the vacuum system exhaust is specific and must not be near the intake for the medical air compressor.

Check Valve [124]
A valve that allows flow in one direction only.

Circle Breathing System [124]
A closed or semi-closed breathing system in which the

CO_2 absorber forms a part of the loop and the flow is unidirectional.

cmH_2O [126]
Centimeter of water pressure.

CO [126]
Carbon monoxide.

CO_2 [126]
Carbon dioxide.

Compliance [126]
A measure of the distensibility of the chest and/or lung; expressed as the ratio of volume change to pressure change (l/cmH_2O).

CO_2 Absorber [124]
A device used to remove CO_2 chemically from exhaled patient gas. Primarily used in the circle breathing system (semi-closed or closed).

Compressed Air [126]
Air at any pressure above atmospheric pressure.

Continuous Positive Airway Pressure (CPAP) [126]
A method of delivering medical gas to a patient in order to hold open alveoli that would normally close at the end of expiration and thereby increase oxygenation and reduce the work of breathing.

COPD
Chronic obstructive pulmonary disease.

Copper Kettle
See **Vaporizer**.

CVP [126]
Central venous pressure.

Cyanosis [126]
A bluish discoloration of the skin, mucous membranes, and nail beds as a result of an oxygen deficiency.

Cylinder (Medical Gas) [124]
Cylinder-shaped tanks that are colored and pin-indexed or CGA valve specific, used to contain specified medical gases. Cylinders range in size from B size (smallest) to H size (largest).

Cylinder Manifold System [126]
A system consisting of two banks of cylinders connected by two pressure regulators and a control that switches from an empty bank of cylinders to a full bank of cylinders when the pressure drops below a predetermined setting.

Cylinder Pressure Gauge [124]
A gauge used to monitor the pressure of gas within the cylinder.

Dalton's Law [112]
Dalton's law of partial pressures states that the pressure exerted by a mixture of gases is equal to the sum of the pressures each gas would exert if it alone occupied the whole volume.
Sample: If barometric pressure equals 760 mmHg, then the partial pressures of these gases would be:

$$\begin{aligned} pO_2 &\ 760 \text{ X } 20.9/100 = 158.84 \text{ mmHg} \\ pN_2 &\ 760 \text{ X } 79.0/100 = 600.40 \text{ mmHg} \\ pCO_2 &\ 760 \text{ X } 0.03/100 = 0.228 \text{ mmHg} \\ \text{p(Residuals)} &\ 760 \text{ X } 0.07/100 = 0.532 \text{ mmHg} \\ \text{Totals} &= 760.0 \text{mmHg} \end{aligned}$$

Dead Space (Alveoli) [126]
The portions of the respiratory tract that are ventilated but not perfused by pulmonary circulation.

Dead Space (Anatomical) [126]
The area in the trachea, bronchi, and air passages containing air that does not reach the alveoli during respiration.

Dead Space (Physiological) [126]
The area in the respiratory system that includes the anatomical dead space together with the space in the alveoli occupied by air that does not contribute to the oxygen-carbon dioxide exchange.

Display [132]
Device that visually indicates quantitative or qualitative information.

DISS [126]
Diameter index safety system.

Diameter Index Safety System (DISS) [126]
An indexed connector system that reduces the risk of delivering the wrong gas to the patient by preventing incorrect connection of medical gas pipes. DISS fittings are used for medical gas-administering devices at pressures of 200 psi or less.

Diaphragm (Anatomical) [126]
The main respiratory muscle separating the abdominal and thoracic cavities. By moving downward, the diaphragm creates suction (negative pressure) to draw in air and expand the lungs.

Diaphragm (Mechanical) [126]
A flexible material that fluctuates with pressure differences.

Diffusion [126]
Movement of a substance (usually a gas or liquid) from an area of higher concentration to an area of lower concentration.

DPM-S [126]
Drager pressure monitoring-self diagnostic.

ECMO
See **Extracorporeal Membrane Oxygenation**.

Endotracheal Tube [126]
The tube inserted into the patient's trachea for ventilation purposes.

$EtCO_2$ [126]
End-tidal carbon dioxide.

Ethylene Oxide (E_2O) [126]
A gas used to sterilize equipment and medical instruments that kills viruses and their spores.

Exclusion System [126]
A mechanical device that prohibits the use of more than one vaporizer at a time.

Exhalation [124]
The act of breathing out.

Exhalation Check Valve [124]
This refers to the valve placed on the CO_2 absorber that allows patient-exhaled gases back into the absorber from the patient circuit.

Exhalation Time [124]
The total length of time an absorbent may be used before it fails to keep the carbon dioxide concentration at an acceptable level.

Exhaust Port [132]
The port through which excess and/or waste gas(es) are discharged either to the atmosphere or to an anesthetic gas scavenging system.

Expected Useful Life [132]
Period during which the performance of an oxygen analyzer or any of its components is expected to meet the requirements of this international standard, when used and maintained according to the accompanying documents.

Expiration [126]
The act of breathing out, or expelling gas from the lungs.

Expiration Reserve Volume [126]
The volume of air that can be exhaled by active contraction of the expiratory muscles at the end of a normal expiration.

Expiratory Port [132]
The opening through which gases and/or vapors pass during expiration.

Expiratory Valve [132]
A valve, which when open, allows gas to pass through it from the patient during the expiratory phase only.

Extracorporeal Membrane Oxygenator (ECMO) [234]
A device that oxygenates the blood of a patient outside the body and returns the blood to the patient's circulatory system. The technique may be used to support an impaired respiratory system.

Fail-Safe Valves [128]
When the main on/off switch is in the 'on' position, oxygen pressurizes and holds open a pressure-sensor shut-off valve. These valves reduce or interrupt the supply of nitrous oxide and other gases (e.g., carbon dioxide, helium, air) to their flow meters if the oxygen supply pressure falls below the threshold setting. This valve, in relation to control of the nitrous oxide supply, is the so-called fail-safe system designed to prevent the unintentional delivery of a hypoxic mixture to the flow meters.

FiO_2 [126]
Fraction of inspired concentration of oxygen (e.g., 0.4 FiO_2 = 40% oxygen).

Fick's Law [184]
The law states, that the rate of diffusion of gases in a gaseous medium is proportional to the gradient of their concentration.

The concentration gradient is simply the difference in concentrations between gases.

Flow Control Valve [124]
The flow control valve, also known as the needle valve, is used to adjust the amount of gas entering the flow meter. This valve is located directly below the flow meters.

Flowmeter Module.
Each gas has its own flowmeter module used to adjust the amount of gas being delivered.

Flow Control Assembly
All of the flowmeter modules put together compose the flow control assembly.

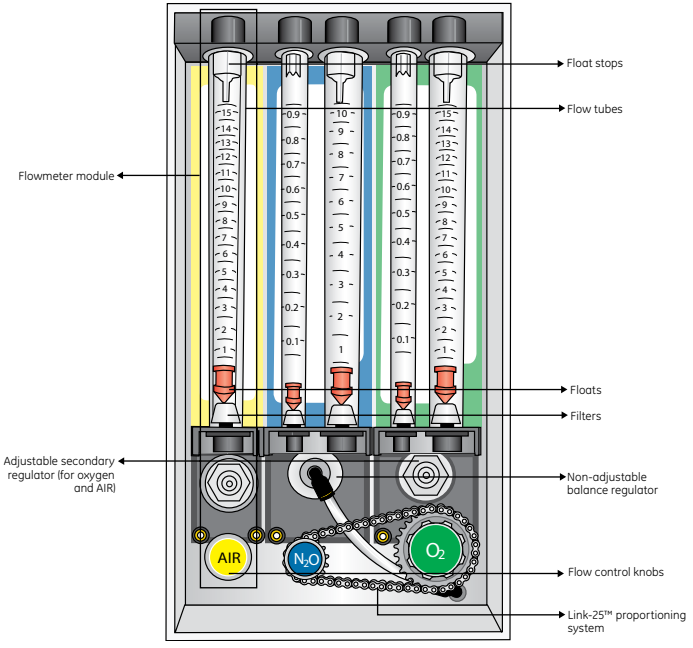


Fig 6.7 - Flow Control Assembly

Flow-Direction Sensitive Component [132]
Component through which the gas flow has to be in one direction only for its proper functioning and/or patient safety.

Flow Directional Valve (Unidirectional Valves) [124]
A valve (e.g., exhalation and inhalation check valves) designed to allow flow in only one direction.

Flow Meter [124]
This device measures the flow rate of the gas passing through it.

Flush Button [126]
A valve with a constrictor located in the outlet port of an anesthesia machine that delivers approximately 55 l/min of oxygen to the breathing circuit. Typically, the flush button is located on the front left corner of the anesthesia machine.

Forced Vital Capacity (FVC) [126]
The volume of gas that can be forcibly exhaled from a maximum inhalation or that can be forcibly inhaled from a maximum exhalation.

Fresh Gas [126]
The mixture of anesthetic gases and vapors intended for delivery to the patient.

Fresh-Gas Inlet [132]
The port on a breathing attachment through which the dispensed mixture from the anesthetic gas delivery module is delivered to the anesthetic breathing system.

Fresh-Gas Supply Tube [132]
Tube conveying fresh gas to a fresh-gas inlet.

Functional Residual Capacity (FRC) [126]
The volume of gas remaining in the lung following a normal tidal expiration.

Gas Cylinder Colors [128]
Gas intended for medical use.

Color coding is used to identify the contents of gas cylinders, fittings, hosing and connections domestically and Internationally.

Agent	USA	ISO
Carbon dioxide	Grey	Grey
He-O_2	Brown/Green	Brown/White
Medical Air	Yellow	Black/White
Nitrogen	Black	Black
O_2-He	Green/Brown	White/Brown
Nitrous Oxide	Blue	Blue
Oxygen	Green	White
Vacuum (Suction)	White	Yellow
WAGD (EVAC)	Purple	Purple
Cyclopropane	Orange	Orange
Helium	Brown	Brown

Table 6.2- Medical Gas Color Coding

Gas Mixture (other than mixtures of oxygen and nitrogen). Color markings of mixtures shall be a combination of colors corresponding to each component gas with the dominate gas first then the minor gas(s).

Gas Mixtures of Oxygen and Nitrogen

19.5% to 23.5% oxygen	Yellow *	Black and White
all other oxygen concentrates	Black and Green	Pink

* Historically, white has been used in the United States, and yellow has been used in Canada, to identify vacuum systems. Therefore, it is recommended that white should not be used in the United States and yellow should not be used in Canada as a marking to identify containers for use with any medical gas.

Gas-Tight Seal [124]
A connection that does not allow bubbling when immersed in water and subjected to a differential pressure.

Gay-Lussac's Law [184]
If the volume and mass remain constant, the pressure exerted by gas varies directly with the absolute (Kelvin) temperature.

$$P_1/T_1 = P_2/T_2$$

P_1 and T_1 = initial pressure and temperature.
P_2 and T_2 = final pressure and temperature.

General Anesthesia [124]
A state of unconsciousness in which there is an absence of pain sensation over the entire body.

Graham's Law [184]
Relates to the diffusion of gas throughout a gaseous medium. The law states that the rate of diffusion of a gas is inversely proportional to the square root of its density or its gram molecular weight. The lower the density of a gas, the more diffusible the gas is.

HFJV (Ventilation) [184]
High frequency jet ventilators.

HFV (Ventilation) [184]
High frequency ventilation.

Henry's Law [184]
Describes the weight of a gas dissolving in a liquid. The weight of a gas dissolving in a liquid at a given temperature is proportional to the partial pressure of the gas. The higher the partial pressure of a given gas, the more it will dissolve.

High-Pressure Circuit [124]
The part of the anesthesia machine circuit that is exposed to cylinder supply pressures.

High-Pressure Hose [124]
A specially designed hose that will handle pipeline supply pressures and is used to connect medical equipment to central system gas sources. Hose can be color-coded and made gas specific through the use of gas specific fittings.

Humidifier [126]
A device used for adding water vapor to inspired gas.

Hyperbaric Oxygenation [126]
Exposure to oxygen greater than 1 atm (760 mmHg).

Hypoxia [126]
A condition of insufficient oxygen supply in the the body's tissue. Gas mixtures containing less than 18-21% oxygen are considered hypoxic.

IMV [184]
Intermittent mandatory ventilation.

I:E Ratio [126]
A ratio of inspiratory time relative to expiratory time.

Inhalation [124]
The drawing of air or other substances into the lungs.

Inhalation Check Valve [124]
The valve placed on the CO_2 absorber that allows the gas mixture to pass through the patient circuit to the patient.

Inspiration [126]
The act of breathing in, or drawing gas into the lungs.

Inspiratory Capacity [126]
The maximum volume that can he inhaled from a resting exhalation; Tidal Volume (TV) + Inspiratory Reserve Volume (IRV).

Inspiratory-Expiratory Valve [132]
Single component that performs the function of both an inspiratory and expiratory valve.

Inspiratory Reserve Volume (IRV) [126]
The volume of gas that can be forcibly inhaled following a normal tidal inspiration.

Inspiratory Valve [132]
The valve, which when open, allows gas to pass through it to the patient during the inspiratory phase only.

Interlock (NIBP/SpO_2) [126]
Electronic circuitry that, when enabled, silences the pulse oximeter alarms when the non-invasive blood pressure module is obtaining a blood pressure sample. This option is used when the cuff and sensor are attached to the same limb (Drager North America specific).

Interference with Measurement Accuracy [132]
Difference between the oxygen reading in the presence of an interfering gas mixture and the oxygen reading in a corresponding mixture in which the interfering gas or vapor fraction has been replaced by nitrogen.

Inspiratory Port (of a Circle System) [132]
The opening through which gases and/or vapors pass during inspiration.

IPPB [184]
Intermittent positive pressure breathing.

IPPV [184]
Intermittent positive pressure ventilation.

IRDS [126]
Infant respiratory distress syndrome.

Key Index Safety System (KISS) [126]
An indexed key system that prevents a vaporizer from being filled with the wrong anesthetic agent. The vaporizer's fill and drain port has pins (keys) that correspond to a keyed adapter for that vaporizer's agent.

Kilopascals (kPa) [126]
Unit of measure for pressure; commonly used in medical instrumentation.

Kinetic Theory [184]
1. Gases are composed of small molecules.
2. Molecules of gas are in constant and random motion.
3. Molecular collisions are completely elastic in nature.
4. Kinetic energy, or kinetic activity, increases in direct proportion to the temperature of the molecules.
5. Molecules of an ideal gas do not attract or repel each other, but travel freely around.

LD50 [126]
The dose of a drug that is lethal in 50% of the population.

Link-25™ Proportioning System
The Link-25 proportioning system is to minimize the chances of delivering a hypoxic mixture to the patient by maintaining a minimum of 25% oxygen in the fresh gas supply (hence the name "Link-25"). **See Fig 6.8.**

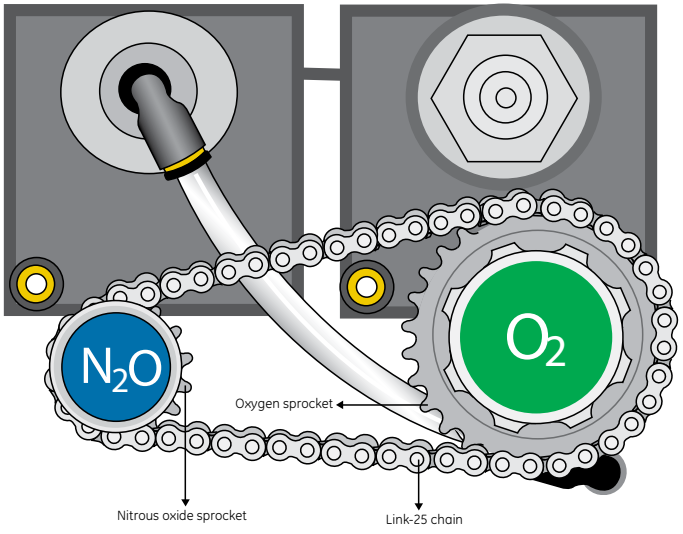


Fig 6.8 - LINK-25™ Proportioning System Assembly

Low-Flow Circuit [124]
This refers to all circuit components located between the flow control valve and the common gas outlet of an anesthesia machine.

MMV [184]
Mandatory minute volume.

MAC [126, 128]
1. Minimum alveolar concentration of an agent needed to produce an anesthetizing effect in 50% of the population.
2. Monitored anesthesia care.

Expression of MAC (vol %) of agent in oxygen as a partial pressure (mmHg) (assuming an ambient pressure of 760 mmHg) [128]

Agent	MAC (vol %)	PMAC1 (mmHg)
Halothane	0.75 x 760 =	5.7
Enflurane	1.68 x 760 =	12.8
Isoflurane	1.15 x 760 =	8.7
Servoflurane*	1.7 x 760 =	12.9
Desflurane*	6.0 x 760 =	45.6
Desflurane*	7.25 x 760 =	55.1

*From Kaloh, T. Ikeda, K *Anesthesiology* 66:301, 1987.
**From Rampil IJ, et al.: MAC is age-related, Ages 18-30 yr., 7.25%; 31-65, 6.0% *Anesthesiology* 74:429, 1991.

Table 6.3 - MAC (VOL%)

Machine End [124]
The end of the component part nearest to the machine.

Malignant Hyperthermia Syndrome [126]
A genetic disease indicated by unexplained tachycardia or elevated temperature (later sign). The disease is more common in children than adults. Dantrolene (administered intravenously) is the drug of choice for treatment.

Manual/Automatic Selector Valve [126]
The valve that routes gas to the appropriate circuit for manual or artificial ventilation.

Medical Air [124]
Air which complies with ANSI Standard Z86.1 Grade F specification.

Medical Gas [124]
Any gaseous substance that meets medical purity standards and has application in a medical environment. Examples are oxygen (O_2), nitrous oxide (N_2O), helium (He), air, nitrogen (N_2), and carbon dioxide (CO_2).

Medical Gas Mixture [124]
A mixture of two or more medical gases to be used for a specific medical application.

Medical Gas Pipeline Supply [126]
A system that consists of a central supply (a manifold, bulk, or compressors), control equipment, piping that extends to points in the facility where non-flammable medical gases are required, and station outlet valves at each point of use.

Minute Volume [126]
The volume of gas inhaled and exhaled in one minute.

MPL Switch [126]
Micro pneumatic logic pressure switch consisting of an internal diaphragm and electrical contact. When the switch is pressurized to a set point, the diaphragm causes the electrical contacts to open or close and produce a specific logic output (Drager North America specific).

NEEP (Ventilation) [184]
Negative end expiratory pressure, used to counterbalance the increase in mean interthoracic pressures caused by **IPPB** with the objective of returning one of the normal mechanisms (negative intrathoracic pressure) for venous return to the right atrium.

Nitrous Oxide [124]
An inorganic compound, one of the oxides of nitrogen. It exists as a gas at atmospheric pressure and temperature, and possesses a sweetish smell. The oxygen in the compound will be released under conditions of combustion, creating an oxygen-enriched atmosphere.

Non-Rebreathing Valve [132]
Valve which prevents the inspiration of expired gas in ordinary usage.

Oxygen [124]
An element which, at atmospheric temperatures and pressures, exists as a colorless, odorless, and tasteless gas. Its outstanding property is its ability to sustain life and to support combustion. Although oxygen is non-flammable, materials that burn in air will burn much more vigorously and create higher temperatures in oxygen or in oxygen-enriched atmospheres.

Oxygen Analyzer [132]
Device that measures and indicates the oxygen level in a gaseous mixture.

Oxygen Flush Valve [124]
A separate valve designed to supply a high volume of oxygen to the breathing system.

Oxygen Failure Protection Device (FPD) [126]
A mechanical device that proportionately restricts the flow of all gas supplies other than oxygen in the event of a partial or complete loss of oxygen.

Oxygen Level [132]
Concentration of oxygen in a gaseous mixture.
Note: This may be expressed in any suitable unit, such as percent by volume or partial pressure in kPa (mmHg).

Oxygen Ratio Controller (ORC) [126]
A mechanical device that inhibits the delivery of a hypoxic gas mixture to the patient by controlling the ratio of nitrous oxide to oxygen (Drager North America specific].

Oxygen Ratio Monitor (ORM) [126]
A mechanical device that monitors pressure changes in the oxygen and nitrous oxide flow rates, and activates an alarm when the oxygen percentage drops below 30% (±5%).

Oxygen Reading [132]
Measured oxygen level as indicated by the oxygen analyzer.

Oxygen Supply Failure Alarm System [124]
This alarm is used to warn the anesthetist that the oxygen pressure supply to the anesthesia machine is low, through depletion or failure.

Partial Pressure [132]
The pressure each gas in a gas mixture would exert if it alone occupied the volume of the mixture at the same temperature.

Patient Circuit [124]
The part of the breathing system that extends from the common gas outlet to the patient interface and includes the CO_2 absorber.

Patient Connection Port [132]
The opening at the patient end of an anesthetic breathing system intended for connection to a tracheal or tracheostomy tube connector or adapter or to a face mask angle piece.

Patient End [124]
The end of the component part nearest to the patient.

Patient Wye [126]
A plastic or metal hose fitting that merges the two branches of the breathing circuit into one at the patient connection.

PEEP (Positive End-Expiratory Pressure) Valve [126]
A valve permanently mounted on the absorber block downstream of the breathing pressure gauge that elevates the baseline pressure at the end of exhalation above atmospheric pressure.

Percent (V/V) Oxygen (or Other Gases) [132]
Level of oxygen (or other gas) in a mixture, expressed as a percentage volume fraction.

Perfusion [126]
The supplying of a tissue with fresh blood, which allows oxygen to diffuse into the tissue.

Pethich Test [126]
A test for checking the proper function of a bain anesthesia breathing system; consists of closing the APL valve, filling the reservoir bag, and pushing the flush button. As a result, the reservoir bag should collapse.

Pipeline Gas [124]
Any medical gas that is delivered by way of a permanently piped, hospital distribution system.

Pin Index Safety System (PISS) [126]
The safety system used on small gas cylinders (size E or smaller) with pressures of 200 psi or greater. The cylinder valves are bored with two pin holes whose locations are specific to the cylinder contents and correspond to pins on the cylinder yokes.

Pop-Off Valve [124]
(See **APL Valve**. Same as adjustable pressure limiting valves).

Pressure Relief Valve [124]
Any device [e.g., Adjustable Pressure Limiting (APL) valve] that will automatically relieve pressure within a specified system. Relief valve may or may not be adjustable.

PSI [124]
Pounds per square inch.

PSIG [124]
Pounds per square inch gauge.

Pneumatic Power Outlet [124]
An accessory outlet, located on an anesthesia machine that supplies a driving gas for auxiliary equipment. Driving gas is normally oxygen.

Pressure Gauge [124]
Any device used to measure pressure within a specific system. Usually calibrated in PSI. Metric system uses kPa (kilopascals).

Pressure Limit Control (PLC) [126]
Mechanical device that limits the peak inspiratory pressure produced by the AV-E ventilator without affecting the preset time base (I:E ratio).

Pressure Relief Valve [124]
Any device [e.g., Adjustable Pressure Limiting (APL) valve] that will automatically relieve pressure within a specified system. Relief valve may or may not be adjustable.

Pressure Sensor System [124]
A system used to help prevent hypoxic mixture (ohmeda specific) from being delivered to the patient in the event of low O_2 pressure or complete O_2 supply failure. Operation is such that when O_2 pressure falls below a specified level, the other gas(es) will be shut down. This system is found mainly in anesthesia machines.

Proportioning System
See **LINK-25™ Proportioning System**.

Regulator [126]
A device used to automatically reduce the pressure of a gas mixture to a safe working pressure.

Residual Volume (RV) [126]
The volume of air that is left within the lung even after a forced exhalation; portion of gas that cannot be exhaled.

Resistance (Airway) [126]
The driving pressure necessary to move a specific volume of gas in a specific period of time; expressed in pressure change per unit of volume per time change ($cmH_2O/l/sec$).

Respiration [124]
The exchange of gases between the alveoli and the blood and tissue.

Respiratory Cycle [126]
The time interval from the beginning of inspiration to the end of expiration.

Respiratory Gas-Conducting Components [132]
All components of the anesthetic ventilator and the anesthetic breathing system that are in contact with the patient's respiratory gas during any form of ventilation.

Respiratory Rate [126]
The number of inspiratory-expiratory cycles per minute.

Respirometer [184]
A device used to measure tidal volume, minute volume, and non-forced vital capacity.

Response Time [132]
Time required for the oxygen analyzer to achieve a 10% - 90% response to a step change in oxygen level.

SaO_2 [126]
Oxygen saturation of arterial blood as determined by blood oximeter.

Scavenging System [124]
An assembly of specific components that serves to collect excessive exhaled gases and exhaust them out of the operating room.

Selector Valve (Bag to Ventilator) [124]
A valve that allows the anesthetist to switch between manual patient ventilation (breathing bag) and mechanical ventilator-controlled breathing.

Sensing Area [132]
Part of the oxygen analyzer that is in direct contact with the gas mixture of which the oxygen level is to be measured.
Note: An example of such a part is the membrane surface of an oxygen-sensing electrode.

Shelf Life [132]
Period during which the oxygen analyzer, or any of its components, is stored in its original container according to the accompanying documents.

SIMV [184]
Synchronized intermittent mandatory ventilation.

Spiromed Sensor (Drager Specific) [126]
The component of volume monitoring system that converts the volume of exhaled patient gas to an electronic signal.

Spirometer [185]
A device used to record respiratory volume.

SpO_2 [126]
Oxygen saturation of arterial blood as determined by pulse oximeter.

Standard Diameters in Millimeters for Hose Connections
Different diameters for hose terminals reduce the possibility of misconnection of hoses in the anesthesia breathing and scavenger systems. Patient hoses are 22 mm and evacuation hoses are 19 or 32 mm.

SvO_2 [126]
Saturation of venous blood with oxygen.

Test Lung [124]
A device that simulates the compliance and resistance in a patient's lung, and is used for testing anesthesia and ventilator function during the pre-use checking procedures.

Thermostability [126]
A condition characterized by a constant temperature.

Tidal Volume [124]
The amount of air that passes into or out of the lungs during each normal respiration; the amount of air exhaled after a normal inhalation.

Torr [124]
A unit of pressure, named after the Italian physicist Torricelli; one Torr = 1 mm Hg @ 0 Deg. C.

Torricelli's Law [184]
As gas flow meets a restriction, the molecules must travel faster in a forward direction than they did previously.

Total Lung Capacity (TLC) [126]
The volume of gas within the lungs following a maximum inspiration, including the residual volume.

Trace Gas Analysis [126]
A test that determines minute levels of various gases (i.e., nitrous oxide, ethylene oxide, formaldehyde) by means of a spectrophotometer.

Unidirectional Valves [124]
This refers to valves that allow breathing system gases to flow in only one direction (e.g., inhalation and exhalation check valves).

Universal Gas Law [184]

$$\frac{\text{P1 (Pressure)} * \text{V1 (Volume)}}{\text{T1 (Temperature)}} = \frac{\text{P 2} * \text{V 2}}{\text{T2}}$$

Useful Life [132]
Period of time during which the performance of an oxygen analyzer or any of its components meets the requirements of this international standard, when used and maintained according to the accompanying documents.

Vacuum [126]
A space absolutely devoid of air; more generally, indicates a partial vacuum, or anything less than 14.7 psi.

Vacuum System [126]
A system consisting of vacuum-producing equipment with pressure and operating controls, shut-off valves, alarm warning systems, gauges, and a network of piping extending to and terminating with station inlets at locations where patient suction is required.

Valid Breath [126]
The breath that is counted when the volume of exhaled patient gas exceeds a specific threshold during the respiratory cycle.

Vaporization [126]
The change of a liquid or solid into a gaseous state, generally through the use of heat.

Vaporizer [124, 126, 128]

A device that converts a liquid anesthetic into a gas or vapor. The most recent (1989) voluntary consensus standard for anesthesia machines (ASTM F1161-88) requires that all vaporizers located within the fresh gas circuit be concentration calibrated and that control of the vapor concentration be provided by means of a calibrated knobs or dials.

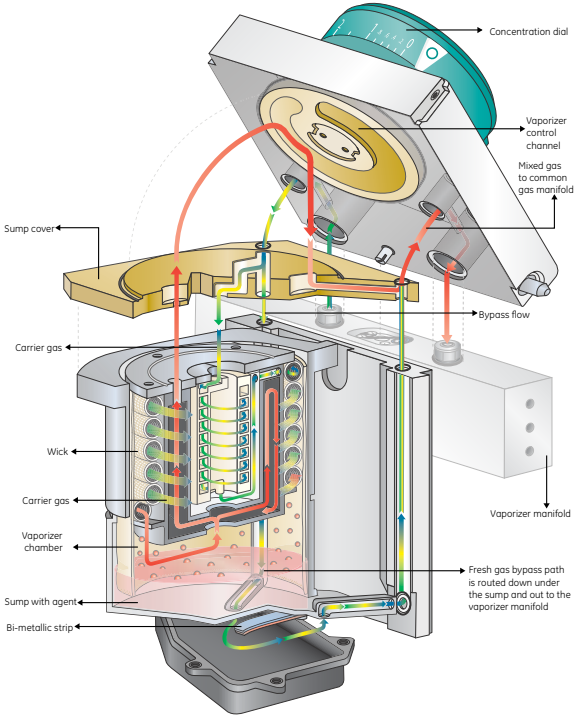


Fig 6.9 - Vaporizer

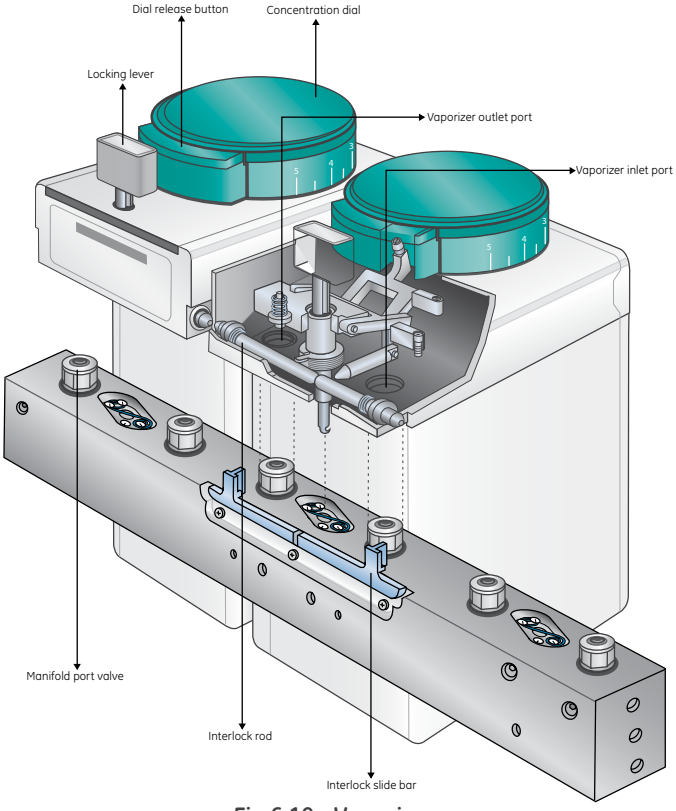


Fig 6.10 - Vaporizer

Vaporizer (Copper Kettle, Verni-Trol) [128]

A vaporizer type using the measured flow systems. The (1989) voluntary consensus standard for anesthesia machines (ASTM F1161-88) requires that all vaporizers located within the fresh gas circuit be concentrated-calibrated and that the control of vapor concentration be provided by means of calibrated knobs or dials. The Copper Kettle, Verni-Trol not mentioned in this standard are now considered by most to be obsolete although military field anesthesia machines still may use such systems).

Vaporizer Interlock System [124]

A mechanical system designed to prevent the use of more than one vaporizer at a time.

Ventilation [124]
The physical process of moving air in and out of the lungs.

Ventilator (Volume Cycled) [136]
Lung inflation is arrested when a preset volume of gas has been delivered to the lungs. A relatively high pressure is developed in the ventilator when a preset volume has been delivered, the gas pressure is reduced to zero, and the expiratory phase takes place. The duration of inspiration depends on the applied pressure, the volume setting on the ventilator, and the lung-circuit resistance and compliance. The next inflation cycle occurs at a time corresponding to the rate setting on the ventilator.

Ventilator (Pressured Cycled) [136]
The airway pressure is sensed at the mouth, while a high positive pressure is developed in the ventilator.

Ventilator (Time Cycled) [136]
The duration of lung inflation is preset. The volume of gas delivered depends on the ventilator pressure and airway resistance and compliance. Electronic, mechanical, or pneumatic circuits can be used to control timing of the inspiratory phase.

Ventilator (Flow Cycled) [136]
Lung inflation is arrested when flow into the trachea ceases. The changeover is affected by using a flow sensor (e.g., pneumotachograph) in the airway. When its output falls to zero, the pressure source is removed and the expiratory phase begins. The volume of gas delivered depends on the pressure, resistance, and compliance of the airway circuit. The next lung inflation occurs in response to the rate setting on the ventilator.

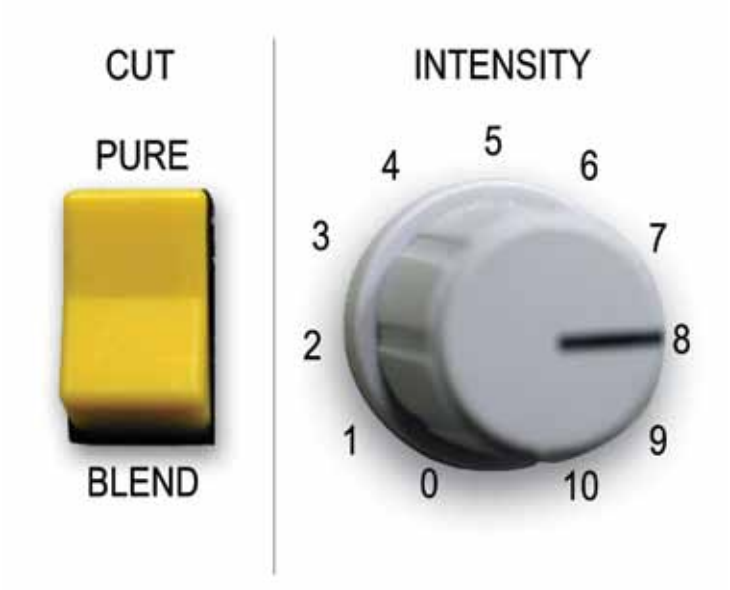
Ventilator Relief Valve [126]
A component of the AV-E that allows waste gases to escape during artificial ventilation.

Venturi [126]
A tube-like device with a constricted middle that is open to atmosphere. As a gas flows through the constriction, the velocity of gas flow increases and its pressure decreases. These conditions create a suction at an opening that entrains outside air, and the resulting gas flow has a greater volume than, but equal pressure to, the original gas stream. In the AV-E, the purpose of a venturi is to augment a flow of pure oxygen with room air for use as drive gas in the ventilator bellows canister.

Warning Signal [132]
Indication of danger, meaning that urgent action is required.

Yoke [126]
A device for mounting compressed gas cylinders to a pneumatic circuit.

07
Electrosurgery



7 – Electrosurgery

ABC
See **Argon Beam Coagulator**.

Accessory, Disposable [282]
An electrosurgical accessory, such as **active electrodes**, handles, **dispersive electrodes**, etc., not intended to be used more than once.

Accessory, Permanent [280]
An electrode, switching pencil, forceps, or other accessory designed to be repairable.

Active Cable [280]
The active cable is the cable between the electrosurgical generator and the **active electrode**.

Active Electrode [108]
The electrode at which the electrosurgical effect is intended. It is usually small in contact surface area and provides a high current density to achieve the intended surgical effect. A **bipolar instrument** is considered an active electrode.

Adaptive REM System [284]
A ValleyLab safety system that continuously monitors impedance levels at the return electrode and adjusts tolerances among patients.

Alternate Site Burn [281]
Alternate site burns are burns that occur when current leaves the body at sites other than the dispersive electrode.

Arc [280]
An electric discharge across an air gap. A true arc takes a relatively long time to become established and is probably not important in electrosurgery. The discharges seen in electrosurgery are referred to as electric **sparks**.

Argon Beam Coagulator (ABC) [283]
Argon beam coagulation (ABC) systems are an adjunct to monopolar electrosurgical units that can provide enhanced coagulation. In argon beam-enhanced coagulation, the electrosurgical current forms an ionized channel, or arc, within an argon gas stream that flows between an electrode and the tissue surface. Argon-enhanced systems provide a tight columnar current channel that is continuous, steady, and easy to control. The argon gas flow also clears blood, or other fluids, and debris from the surgical site, enhancing the surgeon's view and promoting better eschar formation.

Balanced Output [284]
A ValleyLab safety system that monitors the amount of current delivered to the surgical site and the amount recovered at the return electrode, and sets off an alarm at any imbalance. Circuitry used to detect current division on grounded generators prevents alternate site burns.

Bipolar Instrument [108]
Forceps or other electrosurgical accessories having two electrodes, both of which are intended to be applied to the tissue undergoing electrosurgical treatment and energized by the electrosurgical generator so the current produces a surgical effect at both electrodes. It is intended that a substantial portion of the total current is restricted to the tissue between the electrodes.

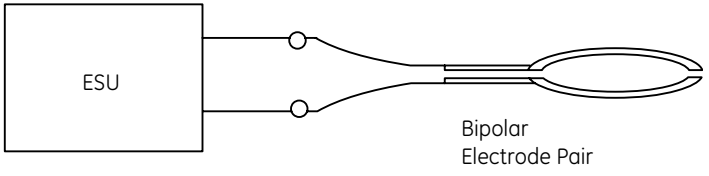


Fig 7.1 – Bipolar Instrument

BLEND [280]
An electrosurgical output, which is intermediate in crest factor between **CUT** and **COAG**. It is best for cutting tissue, while at the same time providing excellent **hemostasis**. Blend can be

thought of as a mixture of **CUT** and **COAG**.

Bovie [283]
Bovie is a registered trademark of MDT Diagnostics Co., to be used only when referring to that device.

Buzzing the Hemostat [284]
A surgical technique for **coagulating** bleeding vessels with current delivered through the hemostat from the **active electrode**.

Cautery [234]
A device or agent that scars and burns the skin, such as in the **coagulation** of tissue by heat or caustic substances.

Cauterize [234]
To burn tissues by thermal heat, including steam, hot metal, solar radiation, or electricity or other agent, including dry ice, usually with the objective of destroying damaged or diseased tissues.

CF
See **Crest Factor**.

Chuckhandle [284]
A disposable **active electrode**; a generic term for an **active electrode**.

COAG [280]
Coagulation, the name of the voltage waveform that is optimized for the **fulguration** of tissue.

Coagulate [280]
In electrosurgery, coagulate is a general term that involves the **fulguration** and desiccation of tissue.

Coagulation [234]
The process of transforming a liquid into a solid, especially of the blood.

Coagulum [282]
The grayish-white substance resulting from the destruction of living tissue by the passage of coagulation current. It normally separates from the underlying living tissue in several hours to several days.

Common Ground Connector [280]
The common ground connector is a cable that connects the metal body of a single puncture laparoscope to the patient return electrode. It is used to shunt capacitive leakage from the metal laparoscope to the patient return electrode.

Crest Factor [281]
The ratio of peak-to-effective (RMS) voltage or current.

$$CF = \frac{\text{peak voltage}}{\text{RMS (effective average) voltage}}$$

A high crest factor is used as an indicator of an electrosurgical unit's ability to coagulate tissue, while a low crest factor is associated with good cutting waveforms. The crest factor of a pure sine wave is 1.4.

Cryocautery [234]
Cryocautery is the application of any substance, such as solid carbon dioxide, that destroys tissue by freezing.

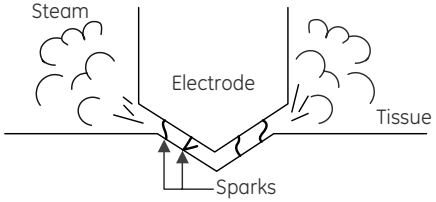
Cryosurgery [234]
Cryosurgery is the use of subfreezing temperature to destroy tissue. A coolant is circulated through a metal probe, chilling it to as low as -160^{0}C, depending on the chemical used. The moist tissues adhere to the cold metal of the probe and freeze. Cells are dehydrated as their membranes burst; they are eventually discarded or absorbed by the body.

Current Density [108]
Current density is the quotient of the current flowing through a given area divided by the area, expressed as amperes per square meter.

CUT [280]

Cut is the name of the voltage waveform or generator output that is optimized for dividing tissue with a minimum of coagulation. It is typically associated with a low crest factor of 1.4 – 2.0.

Electrode is speparated from tissue by a thin layer of steam. Short, intense sparks flask cells into steam. Hemostasis can be minimal and mimics the scalpel.



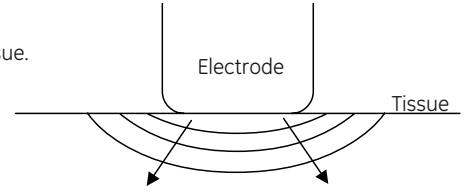
Typical current ≈ 0.1 A_{RMS}

Fig 7.2 – CUT

Desiccate [280]

Desiccation is the dehydration and necrosis of tissue caused by passing a radio frequency electric current through the tissue. In desiccation, the electrodes must be in good electrical contact with the tissue, and the current heats the tissue by dissipating power in the electrical resistance of the tissue. Desiccation differs from fulguration in that there is no sparking between the electrode(s) and the tissue.

Electrode is in good contact with the tissue. Deep coagulation spreads radially Relatively soft, light brown eschar.



Typical current ≈ 0.5 A_{RMS}

Fig 7.3 – CUT

Diathermy [234]

Diathermy is the generation of heat in the body tissues for therapeutic purposes by high frequency electric currents that are insufficiently intense to destroy tissues or impair their vitality.

Dispersive Electrode [108]

The dispersive electrode is the electrode at which no electrosurgical effect is intended. It is usually large in area, compared to the active electrode, promoting a low current density and thereby reducing the possibility or risk of electrosurgical effect or burns.

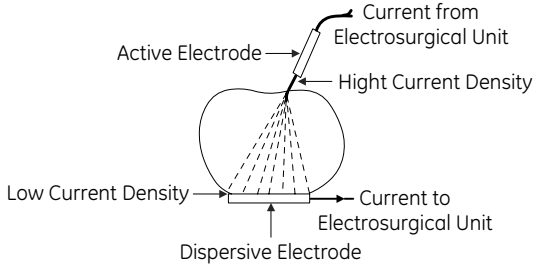


Fig 7.4 – Dispersive Electrode

Coupling to the patient is usually by direct contact with the skin, with or without the aid of a semi-liquid or gel conductive medium. It is also known as a patient plate, plate electrode, return electrode, neutral electrode, inactive electrode, etc. It is sometimes (inaccurately) referred to as a **ground plate**.

Dispersive Electrode Cable [282]

The dispersive electrode cable is the conductor between the electrosurgical generator and the **dispersive electrode**, together with any attached connector.

Dispersive Electrode Cable Monitor [280]

Circuitry or a device, which detects an interruption in dispersive cable continuity between the electrosurgical unit and the **dispersive electrode**.

Duty Cycle [280]

The ratio, usually expressed as a percentage, of the time a waveform is on to the total duration of the on-off cycle (period) of the waveform.

Electrocautery [280]
The coagulation of blood or tissue by means of a conductor heated by electric current passing through the conductor. In contrast to electrosurgery, the electric current does not pass through the tissue, but remains in the wire.

Electrode [280]
An electrode is either terminal of an electric current through which electricity is received or transmitted. In electrosurgery, it is the conductive metal or conductive pad or assembly which actually contacts the patient's body. The electrodes are usually dissimilar in size, and the smaller one, the **active electrode**, is intended to be the site of the electrosurgery, while the larger electrode, the **dispersive electrode**, merely completes the circuit path back to the generator.

Electrosurgery [280]
Electrosurgery is the generation and delivery of a radio frequency current between an **active electrode** and a **dispersive electrode**, or through a **bipolar electrode**, for the purposes of **dehydration**, **necrosis**, **cutting**, and **coagulation**, or other surgical modification of the tissue. In contrast to **electrocautery**, the electric current actually passes through the tissue.

Electrosurgical Accessory [282]
Equipment used in conjunction with the electrosurgical generator to accomplish electrosurgery. These include, but are not limited to, footswitch, cable, **dispersive electrode**, and **active electrode**.

Electrosurgical Circuit [284]
Electrosurgical circuit is the path traveled by the therapeutic current, from the **generator** to the **active electrode** and through the body tissue to the **return electrode** and back to the generator.

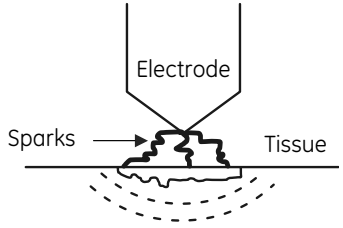
Electrosurgical Unit [282]
Electrosurgical unit (ESU) is the electrosurgical generator, together with its accessories, intended for use to perform electrosurgery. It is sometimes (inaccurately) referred to as a **Bovie**.

Eschar [234]
Eschar is a scab or dry crust resulting from a thermal or chemical burn, infection, or excoriating skin disease.

ESU
See **Electrosurgical Unit**.

Fulguration [280]
Fulguration is the **coagulation** of tissue or blood by means of radio frequency electric sparks. In contrast to **desiccation**, the **active electrode** is not in good electrical contact with the tissue and sparks jump from the electrode to the tissue. Fulguration is literally capable of reducing tissue to carbon.

Electrode free from tissue. Long sparks to tissue result in superficial coagulation first, then deeper necrosis as fulguration continues. Eschar is hard and black.



Typical current ≈ 0.1 A_{RMS}

Fig 7.5 – Fulguration

Generator [284]
The machine that converts low-frequency alternating current to high-frequency electrosurgical current.

Grounded Generator Output [282]
An electrosurgical generator output which has the **dispersive electrode** grounded to the metal chassis of the generator. This means that current will flow from the **active electrode** when it touches any grounded object in the room.

Grounded Plate [208]
A patient **return electrode**, which is connected directly to earth ground.

Hemostasis [234]
Hemostasis is the termination of bleeding by mechanical or chemical means or by the complex **coagulation** process of the body.

Inactive Electrode
See **Dispersive Electrode**.

Isolated Generator Output [280]
A generator output which has no reference to ground. In order for current to flow, there must be a complete circuit path from the active terminal all the way around to the patient terminal.

Microbipolar [282]
A bipolar mode with low power output designed to allow fine contact in critical areas.

Mode, Operating [282]
Each of the distinct ways in which the electrosurgical unit can be operated with electrosurgical output, such as monopolar cutting, monopolar coagulation, monopolar blended, monopolar spray, bipolar coagulation, and bipolar cutting.

Monopolar [282]
The traditional form of electrosurgery that uses an **active electrode** to apply the current to the surgical site, and a **dispersive electrode** to return the current to the electrosurgical unit.

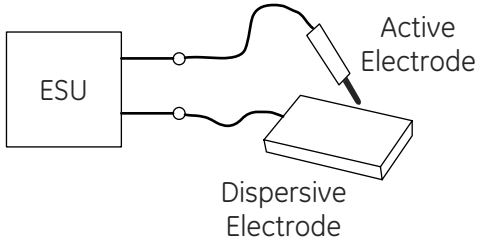


Fig 7.6 – Monopolar

Necrosis [234]
Localized tissue death that occurs in groups of cells in response to a disease or injury.

Neutral Electrode
See **Dispersive Electrode**.

Open Circuit [280]
No load or resistance connected to a voltage source. For example, if the generator is activated and the **active electrode** is not touching any tissue, the output of the generator is said to be open circuit.

Open Circuit Peak Voltage [282]
The maximum instantaneous output voltage of the electrosurgical waveform under the condition of no intentional load.

Output Power [282]
The rate of delivery of electrosurgical energy as determined by the measurement of the RMS current in a non-reactive load resistance and/or the RMS voltage across the load resistance.

Patient Circuit Safety Monitor [282]
Any circuit in an electrosurgical unit designed to detect an unsafe condition in the output circuit and to give a warning or disable the generator.

Patient Electrode
See **Dispersive Electrode**.

Patient Plate
See **Dispersive Electrode**.

Patient Sentry™ [284]
A circuit alarm system (manufactured by Sybron-Ritter) that monitors the continuity of the electrosurgical circuit with low-voltage direct current but does not detect current, division, nor measure the quality of contact at the **return electrode**.

Pencil
See **Active Electrode**.

Pin Point Coagulation [282]
A procedure wherein a small amount of tissue on the surface is dried out by placing the active electrode in contact with the tissue.

Power [280]
Power is the rate at which energy is produced or consumed. The unit of measure of power is the watt.

Radio Frequency [282]
Radio- frequency (RF) is a high frequency alternating current, usually greater than 100,000 Hz that will produce electromagnetic radiation.

Radio Frequency Leakage Current [280]
The maximum current that can flow to ground from an **isolated generator** output when one side of the output is wired directly to earth ground.

Return Electrode Monitor (REM) [284]
Safety system that continuously monitors impedance levels at the return electrode, sets an alarm and disables the ESU if it detects dangerous levels of impedance caused by current concentration or lack of continuity.

Return Electrode Monitor
See **REM**.

Return Fault Circuit [280]
The return fault circuit is a patient safety circuit monitor unique to the ValleyLab SSE3B and SSE4 electrosurgical generators, which monitors the integrity of the patient's contact with the return electrode, the integrity of the patient's cable, and other safety features.

RF
See **Radio Frequency**.

Plate Electrode
See **Dispersive Electrode**.

Return Electrode
See **Dispersive Electrode**.

S-Cord [280]
The S-cord is a cable that connects a patient **return electrode** to the metal body of a colonscope. It is used to shunt capacitive leakage from the colonscope to the patient **return electrode**.

Spark [280]
A spark is an electronic discharge across an air gap. In electrosurgery, it is the discharge seen at the end of an electrode when cutting or fulgurating.

Spark-Gap [280]
Spark-gap is a pair of electrodes mounted in a circuit and positioned so that voltage will cause sparks to jump across the air gap when the voltage rises to a high enough level. These are used in primitive electrosurgical generators as a type of voltage-controlled switch for the generation of COAG waveforms. In function, they are analogous to the breaker points in an automobile ignition.

Spark-Gap Waveform [280]
An electrosurgical COAG output generated by a spark-gap generator.

Stand-By Mode [108]
The mode in which the generator and control circuitry are energized, but the electrosurgical output currents are not activated. It is sometimes referred to as idle mode.

Surgical Diathermy [280]
The British term for electrosurgery.

Testing, Dispersive Electrode Grounding Resistance [283]
The resistance between the dispersive electrode and the ground pin of the power cord should indicate an open circuit (> 20MΩ) for **isolated-output** units or grounded units equipped with a capacitor between the dispersive electrode and ground. An initial low resistance that drifts up to a value over 20MΩ is acceptable; this phenomenon is due to a charging capacitor. The resistance between the dispersive electrode and the ground pin of the power cord should indicate a short circuit (≈ 0.15 Ω) for grounded-output units without a capacitor.

Testing, Output Current [283]
Output power should be tested according to the manufacturer's recommendations. If the electrosurgical analyzer does not have the load resistance suggested by the manufacturer, it can still be used, but the output powers may be different from those given in the service manual. Test the unit at the manufacturer's recommended output settings or at a typical clinical setting (at a dial setting about 1/3 of maximum). Using all the operating modes available on the electrosurgical unit, record the output current or power from the meter. Compare the output power to the manufacturer's specifications.

Testing, Output Isolation [283]
This test is intended only for isolated output units to determine whether the isolation has been degraded. Connect the output current/power meter between the active cable and a ground (e.g., the chassis of the unit). The dispersive cable and dispersive electrode must not be in contact with the ground. **CAUTION: To avoid the possibility of burns, do not touch the electrode**. With the unit in pure cut or cut 1 mode, increase the controls gradually to one of the moderate levels used in the output power test and record the power to ground. The extent of output reduction compared with the output recorded in the output power test is an indication of the degree of isolation.

$$\text{Isolation \%} = 1 - \frac{\text{Power (W) of isolation test}}{\text{Output power (W) at the same setting}}$$

$$\text{or} = 1 - \frac{\text{Current}^2\text{ (A) of isolation test}}{\text{Output current}^2\text{ (A) of same setting}}$$

Isolation should meet the manufacturer's specifications or be ≥ 80%.

Testing, Waveform Analysis [283]
If a manufacturer has provided output waveform characteristics such as frequency, waveform repetition or burst rate, waveform on-off time, these may be studied and documented by using an oscilloscope connected to the appropriate jack on the output power/current meter. This test is optional.

08
Clinical Laboratory

8 – Clinical Laboratory

Clinical Laboratory
Each hospital has a department called the Clinical Laboratory, frequently referred to as "the lab". The size and complexity of the lab can vary greatly. The lab is under the auspices of the Pathologist, who is a medical doctor and is organized and directed by a Laboratory Director, who is a medical technologist. The employees of the lab are medical technologists or medical technicians, who are usually certified by the ASCP, American Society of Clinical Pathologists. An ASCP certification means that the person took a standardized test, which is designed by the organization and passed this test. Some labs also have phlebotomists who are trained healthcare workers who draw the patient's blood for sample testing.

Laboratory
The laboratory is divided into unique and specific departments or sections based on the type of testing that will be performed. Each of these departments or grouping of department has a department supervisor. The departments are Hematology, Coagulation, Urinalysis, General Chemistry that can include Special Chemistry and Drug Testing, Microbiology that can include Mycology and Parasitology, Blood Banking, Histology, and Pathology.

Hematology
Hematology is the study of the cells in the blood. There are different types of white blood cells. Each type of white blood cell has a unique function in the body. White blood cells are increased when there is an infection in the body. The red blood cells carry the oxygen around the body and are decreased in patients with anemia.

Coagulation
Coagulation is the study of the clotting of the blood. The platelets "clump" together to form a clot to control bleeding, aided by various clotting factors in the blood.

Urinalysis
Urinalysis is the examination of a patient's urine. There is known criteria for a urine sample and if there is deviation, the results can be used to help diagnose a patient.

General Chemistry
General Chemistry is the study of the chemicals that are in the blood. These chemistries are listed in the chemistry panels, explained below.

Special Chemistry
The Special Chemistry department can perform a variety of tests, ranging from allergy testing, hepatitis testing, and HIV testing.

Drug Testing
Drug testing can be Drugs of Abuse and/or Therapeutic Drug testing. Examples of Therapeutic drugs are digoxin, which can be prescribed for heart conditions, and theophylline for asthma.

Microbiology
The Microbiology department is where specimens are plated in Petri dishes and then incubated. What grows and what does not grow is used to identify the causative agent, which is then used for diagnosis. The **Mycology** department is part of the microbiology department and in this department tests are performed to identify specifically yeasts/fungi. **Parasitology** is another department within the microbiology department and this is where parasites/bugs are identified.

Blood Banking
Blood banking is the department where a patient's blood is determined for the blood type and the absence or presence of specific antibodies and antigens. This information is used should the patient require the administration of a blood transfusion.

Histology

Histology is the department where tissues are analyzed. The tissue is sliced extremely thin, placed on a slide and stained for review under a microscope. Trained histologists and/or pathologists then review the tissue slides to determine the presence or absence of cancer cells.

Pathology

Pathology is where autopsies are performed.

The lab can and will analyze a variety of body fluids. Examples of body fluids that are used, as specimens are blood, spinal fluid, urine, stools samples, and swabs from wounds or parts of the body. The most common specimen is blood. The blood, drawn by a qualified health care provider, is collected into a special tube and is delivered to the lab for testing. These special tubes have different colored caps to distinguish the different additives and hence the different test(s) the lab will perform on the specimen. Examples of common collection tubes are listed below. Their cap color, additive, and use are included.

Examples of Common Collection Tubes

CAP COLOR	ADDITIVE	SPECIMEN TYPE AND LAB USE
Dark Green	Lithium Heparin or Sodium Heparin	Plasma. Chemistry
Light Green with black marbling	Lithium Heparin with Gel Separation	Plasma. Chemistry
Orange with black marbling	Clot activator and Gel Separation	Serum. Chemistry
Red	Clot activator in plastic	Serum. Chemistry and Serology
Purple	Liquid K_3EDTA in glass or Spray-coated K_2EDTA in plastic	Whole blood. Hematology
Light Blue	Sodium Citrate	Plasma. Coagulation

Table 8.1 - Examples of Common Collection Tubes

After the specimen is drawn, it is delivered to the lab. If the lab is automated, the lab personnel will enter the patient demographics and test(s) required into the lab information computer system. A barcode may be generated for identification and placed on the tube or specimen. The specimen is then sent to the appropriate department of the laboratory for testing.

Some samples require centrifugation. After the blood specimen is allowed to clot, the tube is placed in a centrifuge. The speed and length of centrifugation depends on the sample tube type and the test requirements.

Common Lab Terms and their Definitions

TERM	DEFINITION
Stat	Derived from the Latin word, statim. It means 'immediately'.
Serum	Derived from whole blood, which is allowed to clot, and is then centrifuged. Cells are forced to the bottom of the tube and the fluid that remains at the top is the serum. It should be clear and yellow.
Plasma	Derived from whole blood, which has **not** clotted and is then centrifuged. Cells are forced to the bottom and the fluid that remains at the top is the plasma. This sample is not clear.
Accuracy	Degree of closeness to a true (actual) value. Using the dart-board example, accuracy is the degree of closeness to the bulls-eye.
Precision	Degree under the exact same conditions to get a consistent result. Also known as reproducibility. Using the dartboard example, precision is the degree of each dart hitting the board in the exact same place.
Linearity	A method to verify that a reaction will provide the true answer (concentration) over a range from a minute level to high level.
QA-Quality Assurance	A program to systematically monitor tests performed in the lab.
QC-Quality Control	Part of a QA Program, running samples with known quantities to verify correct operation.
Levy Jennings	A graphical display (chart) of the assay values over time. The mean is plotted in the middle with +/- 2 standard deviation (SD).
	Drift is when 3 data points trend in a particular direction.
	Shift is an abrupt change in the data points.
CLIA'88	Clinical Laboratory Improvement Amendments of 1988
CAP	College of American Pathologists
Proficiency Testing	Blind samples sent to the lab to verify each test performed in the lab will have comparable results with other laboratories using the same method.

TERM	DEFINITION
Statistical Terms	Mean is the average of a set of numbers.
	Mode is the value which occurs with the greatest frequency.
	Median is the middle number in the set.
	Range is the difference between the highest and lowest number.
	Standard Deviation is the degree to which the data vary around the mean.
	Coefficient of Variation is expressed as a percent and reflects the variability among the results, increased CV shows decreased precision.
ISE-Ion Selective Electrode	Method used to measure analytes, most commonly sodium, potassium and chloride.

Table 8.2 – Common Lab Terms and Definitions

Tests and Panels

The number of tests performed in a lab can vary greatly, depending upon the size of the lab, the size and type of hospital or facility that is utilizing the lab and the instrumentation that is present. There are over 700 tests that can be performed in a large, well-equipped lab. Listed are some basic panels of test that are performed in the average lab. Medicare dictates the tests included in these major panels. Remember, these panels can and do vary.

Basic Metabolic Panel

BUN, Calcium, Carbon Dioxide, Chloride, Creatinine, Glucose, Potassium, and Sodium

Comprehensive Metabolic Panel

Basic Metabolic Panel tests plus Albumin, Total Bilirubin, Alkaline Phosphate, Total Protein, SGOT (AST), and SGPT (ALT)

Electrolyte Panel

Carbon Dioxide, Chloride, Potassium, and Sodium

Acute Hepatitis Panel

Hepatitis A Ab, IgM; Hepatitis B Core Ab, IgM; Hepatitis B Surface Ag, and Hepatitis C Ab (Ab = antibody, Ag = antigen)

Lipid Panel

Total Cholesterol, HDL (High Density Lipid) Cholesterol, LDL (Low Density Lipid) Cholesterol, and Triglycerides

Liver Panel

Albumin, Total and Direct Bilirubin, Alkaline Phosphate, SGOT (AST), and SGPT (ALT)

Renal Function Panel

Basic Metabolic Panel plus Albumin and Phosphorus

CBC – Complete Blood Count

White Blood Cell Count (WBC), Red Blood Cell Count (RBC), Hemoglobin (HGB), Hematocrit (HCT), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC), Relative Distribution Width (RDW), Platelets, and Mean Platelet Volume (MPV)

CBC with Differential

Commonly termed as **CBC with Diff**, it includes CBC tests plus an analysis of the different white blood cells and red blood cells that are present, both absolute number and percentage – Lymphocytes (LYMP), Monocytes (MONO), Neutrophils (NEUT), Eosinophils (EOS), and Basophils (BASO)

Normal Ranges

Normal ranges for every test will vary with the population demographics, area of the country, and the age and sex of the patient. Each facility will establish normal ranges for their particular patient population. Below is a list of common tests performed in a lab and the suggested reference range.

CHEMISTRY RANGES	MALE NORMAL RANGE	FEMALE NORMAL RANGE
Sodium	133 -145 mmol/L	133 - 145 mmol/L
Potassium	3.3 - 5.1 mmol/L	3.3 - 5.1 mmol/L
Chloride	99 - 111 mmol/L	99 - 111 mmol/L
Carbon Dioxide	21 - 32 mmol/L	21 - 32 mmol/L
BUN	70 - 105 mg/dl	70 - 105 mg/dl

CHEMISTRY RANGES (CONT.)	MALE NORMAL RANGE	FEMALE NORMAL RANGE
Creatinine	6 - 25 mg/dl	6 - 25 mg/dl
Calcium	8.0 - 10.5 mg/dl	0.5 - 1.3 mg/dl
Albumin	3.2 - 5.2 g/dl	3.2 - 5.2 g/dl
Total Protein	5.9 - 8.4 g/dl	5.9 - 8.4 g/dl
SGOT (AST)	0 - 45 U/L	0 - 45 U/L
SGPT (ALT)	0 - 50 U/L	0 - 50 U/L
Alkaline Phosphate	35 - 135 U/L	35 - 135 U/L
Total Bilirubin	0.3 - 1.2 mg/dl	0.3 - 1.2 mg/dl
HEMATOLOGY RANGES		
WBC	4.0 - 11.5 k/mm3	4.0 - 11.5 k/mm3
RBC	3.80 - 5.50 m/mm3	3.60 - 5.00 m/mm3
Hemoglobin	12.8 - 17.5 g/dl	11.3 - 15.5 g/dl
Hematocrit	36.0 - 50.0 %	34 - 46.5 %
MCV	80.0 - 100.0 fL	80.0 - 100.0 fL
MCH	27.0 - 34.0 pg	27.0 - 34.0 pg
MCHC	32.0 - 36.0 g/dl	32.0 - 36.0 g/dl
RDW	11.5 - 14.5 units	11.5 - 14.5 units
PLT	140 - 400 k/mm3	140 - 400 k/mm3
MPV	6.5 - 10.0 fL	6.5 - 10.0 fL
LYMP%	15 - 40 %	15 - 40 %
MONO%	3 - 12 %	3 - 12 %
NEUT%	43 - 80 %	43 - 80 %
EOS%	0 - 5 %	0 - 5 %
BASO%	0.0 - 1.2 %	0.0 - 1.2 %
Sedimentation Rate	0 - 20 mm/hr	0 - 30 mm/hr
COAGULATION RANGES		
PT	8.5 - 13.0 SECS	8.5 - 13.0 SECS
APTT	23.0 - 38.0 SECS	23.0 - 38.0 SECS
FBG	195 - 451 mg/dl	195 - 451 mg/dl
URINALYSIS		
Color	Straw - Amber	Straw - Amber
Appearance	Clear	Clear
Glucose	Negative, mg/dl	Negative, mg/dl
Bilirubin	Negative	Negative

URINALYSIS (CONT.)	MALE NORMAL RANGE	FEMALE NORMAL RANGE
Ketone	Negative, mg/dl	Negative, mg/dl
Specific Gravity	1.003 - 1.035	1.003 - 1.035
Blood	Negative	Negative
pH	5.0 - 8.0	5.0 - 8.0
Protein	Less than or equal to 30	Less than or equal to 30
Urobilinogen	0.1 - 1.0 EU/DL	0.1 - 1.0 EU/DL
Nitrite	Negative	Negative
Leukocytes	Negative	Negative
Squam Epi	0 - 1/HPF	Less than 5/HPF
Urine RBC	Less than 5/HPF	Less than 5/HPF
Urine WBC	Less than 5/HPF	Less than 5/HPF
Casts	Less than 3/LPF	Less than 3 Hyaline/LPF
Bacteria	None seen/HPF	None seen/HPF
Mucous		Less than 2+/HPF
Crystals	None seen/HPF	None seen/HPF

Table 8.3 – Suggested Reference Range for Common Laboratory Tests

Critical Values

Critical values are test results that may be life threatening. These results should be called to the health care provider for that particular patient, regardless of the hour of the day or night. Below is a list of some typical Critical Values that were identified by the hospital laboratory and the attending healthcare providers.

TEST	LOW	HIGH
Total Bilirubin – newborn	None	>12 mg/dl
Calcium	<6 mg/dl	>14 mg/dl
Glucose	<50 mg/dl	>500 mg/dl
Glucose – newborn	<30 mg/dl	>200 mg/dl
Glucose – pediatric	<40 mg/dl	>200 mg/dl
Magnesium	<1.0 mg/dl	>4.9 mg/dl
Phosphorus	<1.1 mg/dl	
Potassium	<3.0 mmol/L	>6.2 mmol/L
Potassium – newborn	<2.5 mmol/L	>8.0 mmol/L
Sodium	<120 mmol/L	>160 mmol/L

TEST	LOW	HIGH
Bicarbonate	<10 mmol/L	>40 mmol/L
Blood Lead	None	>50 mcg/DL
Blood Lead – children	None	>10 mcg/DL
Serum PSA	None	>10 ng/ml
Troponin	None	>0.77 ng/ml
Serum Drug Levels	Toxic Levels	
WBC – excluding cancer patient	<1.0 k/mm3	>50.0 k/mm3
Hct – adult	<21 %	>60 %
Hgb – adult	<7 gm/dl	>20 gm/dl
Platelet	<30 k/mm3	>1000 k/mm3
APTT	None	>100 seconds
Fibrinogen	<100 mg/dl	

Table 8.4 – Typical Critical Values Obtained in a Hospital Laboratory

Critical Values for Therapeutic Drug Levels

DRUG	TOXIC LEVEL
Acetaminophen	>50 ug/ml
Amikacin	
Trough	>10 ug/ml
Peak	>30 ug/ml
Carbamazepine	>15.0 ug/ml
Digoxin	>2.4 ng/ml
Gentamycin	
Trough	>2.0 ug/ml
Peak	>12 ug/ml
Lithium	>2.0 mmol/L
Phenobarbital (Dilantin)	>60 ug/ml
Salicylates	>30 ug/ml
Theophylline	>30 mg/dl
Tobramycin	
Trough	>25 ug/ml
Peak	>2.0 ug/ml
Valproic Acid (Depakine)	>12 ug/ml
Vancomycin	
Trough	>20 ug/dl
Peak	>60 ug/ml

Table 8.5 – Critical Values for Therapeutic Drug Levels

09
Ultrasound Physics

9 – Ultrasound Physics

Acoustic Impedance [223, 224]

Acoustic impedance is a measure of the resistance to sound passing through a medium. Differences in acoustic impedance result in boundaries at the interface of two tissue types. Depending on the magnitude of this difference, sound waves can be transmitted through, reflected off of, or refracted at tissue interfaces. Acoustic impedance is equal to (the **density (ρ)** multiplied by the **propagation** speed (c).)

$$z = \rho c$$

Impedance is determined by the **density** and **stiffness** of a medium, but does not depend on frequency. Typical units Rayl, which equals $1 kg/m^2s$ or $0.1 g/cm^2s$.

Tissue	Acoustic Impedance (10^6 Rayls)
Air	0.0004
Fat	1.38
Water	1.48
Soft tissue (average)	1.63
Kidney	1.62
Liver	1.65
Blood	1.61
Muscle	1.70
Bone	7.80

Table 9.1 - Acoustic Impedances in Biological and Nonbiological Materials [222]

Acoustic Velocity

See **Propagation Speed**.

Aliasing [221]

Improper **Doppler** shift information from a pulsed Doppler or color flow instrument when true Doppler shift exceeds one half the pulse repetition frequency.

Attenuation [222]

The loss of strength of the acoustic waves as they travel through a medium. In propagating through tissue, the acoustic waves will be attenuated by three different causes: Attenuation = Beamwidth + Scatter + Absorption. Attenuation coefficient (a, ac) is typically expressed in units of dB/cm and is dependent upon the medium of propagation and the frequency (f) of the wave. (See also **Half-Intensity Depth**.)

Medium	Attenuation (dB/cm at 1 MHz)
Bone	15
Air	12 (f^2)*
Kidney	1.0
Liver	0.94
Soft tissue (average)	0.70
Fat	0.63
Blood	0.18
Water	0.002 (f^2)*

* f^2 indicates a quadratic frequency dependency of these attenuation coefficients.

Table 9.2 – Typical Values of Ultrasonic Attenuation Coefficients [222]

Frequency (MHz)	Average Attenuation Coefficient for Soft Tissue (dB/cm)
1.00	0.5
2.25	1.1
3.50	1.8
5.00	2.5
7.50	3.8
10.00	5.0

Table 9.3 – Average Attenuation Coefficients in Tissue [221]

Axial [221]

Axial resolution is in the direction of the transducer.

Axial Resolution [221]

Axial resolution is the minimum reflector separation along the sound path that is required to produce separate echoes.

Color Flow [221]

Color Flow is the presentation of a two-dimensional, real-

time **Doppler** or time-shift information superimposed on a real-time, gray-scale anatomic cross-sectional image. Flow directions toward and away from the transducer are presented as different colors on the display.

Continuous Wave [221]
Continuous wave (CW) is a wave in which cycles repeat indefinitely, not pulsed.

Contrast Resolution [221]
Contrast resolution is the ability of a gray-scale display to distinguish between echoes of slightly different amplitude or intensity.

CW
See **Continuous Wave**.

dB
See **Decibel**.

Decibel [221]
Decibel is a unit of power or intensity ratio. The number of decibels is 10 times the logarithm (base 10) of the power or intensity ratio.

Density [221]
Density is the concentration of matter (mass per unit volume) of a medium. As the density increases, the propagation speed through the medium decreases.

Detail Resolution [221]
Detail resolution is the ability to image fine detail and to distinguish closely spaced reflectors. See **axial resolution** and **lateral resolution**.

Doppler Angle (θ) [221]
Doppler angle (θ) is the angle between the sound beam and the flow direction.

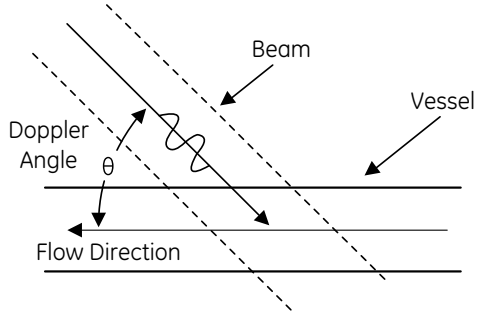


Fig 9.1 – Doppler Angle

Doppler Effect [221]
Doppler effect is the frequency change of a reflected sound wave as a result of reflector motion relative to the transducer.

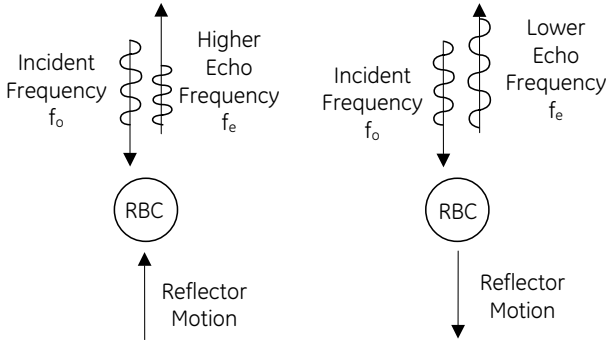


Fig 9.2 – Doppler Effect

$$f_D = f_e - f_o = \frac{2 f_o \, v \cos\theta}{c}$$

where:

f_D = Doppler shift (MHz)
f_e = Echo frequency (MHz)
f_o = Operating frequency (MHz)
v = Reflector speed (m/s)
θ = The angle formed between the incident wave and the path of the reflector
c = Propagation speed of the reflector

Duplex Scan [221]
A duplex scanner provides a combination of both ultrasound imaging and **Doppler** technology.

Duty Factor [221]
Duty factor (also duty cycle) is the fraction of time a sound wave (in the form of pulses) is on. It is calculated by dividing the pulse duration by the pulse repetition period. The duty factor is unitless.

$$\text{Duty Factor} = \frac{\text{Pulse Duration}}{\text{Pulse Repetition Period}}$$

Frequency [222]
Frequency (f) is the basic repetition time of a wave or the number of high or low pressure waves crossing each area of tissue each second. Typical units are Hertz (Hz).

Half-Intensity Depth [221]
Half-intensity depth is the depth of tissue at which the intensity of the sound wave is reduced to one half of what is at the surface. It is dependent upon the propagation medium and the frequency of the wave.
(See also **Attenuation Coefficient**.)

Impedance
See **Acoustic Impedance**.

Intensity Reflection Coefficient [221]
Intensity reflection coefficient (IRC, R, G) is the fraction of sound wave reflected from the reflector (target). The magnitude of reflection is determined by the acoustical impedance difference between two mediums at a boundary. Reflection coefficient is unitless.

$$R = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$$

Laminar Flow [221]
Laminar, or parabolic flow, is flow in which fluid layers slide over each other to produce a parabolic flow speed profile.

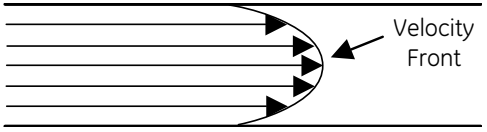


Fig 9.3 – Laminar Flow

Lateral [221]
Lateral is perpendicular to the direction of sound travel.

Lateral Resolution [221]
Lateral resolution is the minimum reflector separation perpendicular to the sound path required to produce separate echoes.

Operating Frequency [221]
Operating frequency is the preferred (maximum efficiency) frequency of operation of a **transducer**.

Parabolic Flow
See **Laminar Flow**.

Period
The period (T) of a wave is the time it takes for one complete cycle of a wave to occur is the period (T) of that wave. The period is equal to one over the frequency (f) and has units of seconds.

$$T = \frac{1}{f}$$

Phantom [221]
Phantom is a tissue-equivalent device that has some characteristics representative of tissues, such as scattering or attenuation properties.

Propagation Speed [221]

Propagation speed is the speed at which sound can travel through a medium, and is determined only by the characteristics of the medium-density and stiffness. Propagation speed increases as stiffness increases or density decreases. Typical units are m/s or mm/μs.
(See also **Acoustic Velocity**)

Tissue	Propagation Speed (m/s)
Air	330
Fat	1,450
Water	1,480
Soft tissue (avg.)	1,540
Kidney	1,560
Liver	1,550
Blood	1,570
Muscle	1,580
Bone	4,080

Table 9.4 – Average Speed of Sound in Biological and Non-biological Materials [222]

Pulsatile Flow [221]

Pulsating flow is flow that accelerates and decelerates with each cardiac cycle.

Pulsed Ultrasound [221]

Ultrasound produced in pulse form by applying electric pulses to the transducer.

Real-Time Display [221]

A display that continuously images moving structures or a changing scan plane.

Scanning Modes [223]

- **A-mode** scanning refers to the amplitude mode scanning that measures tissue discontinuity along the scan axis. A-mode displays the magnitude of the signal as a spike in one dimension, Y, versus the depth or time for return of the echo signal in the other dimension, X.
- **B-mode** scanning produces a two-dimensional image of the tissue under study by combining A-mode signals from various directions through mechanical transducer scanning.
- **M-mode**, or time motion scanning (formerly TM-mode), is an extension of the A-mode approach, in which a single stationary transducer is used. The depth of the echo is displayed on the vertical axis; the brightness of the display is modulated by the echo amplitude. M-mode scanning is very useful in evaluating moving structures, such as valves of the heart and the motion of the heart wall. This application of M-mode scanning is known as echocardiography.
- **Real-time mode**, or rapid B-scanning techniques, provides continuous data acquisition at a rate sufficient to give the impression of instantaneous motion of moving structures. Real-time scanning is used extensively in obstetrics, as no ionizing radiation is involved. It has also found applications in vascular imaging of major vessels and quick localization of structures to identify areas for further evaluation with static B-mode imaging.
- **Doppler** scanning relies on the presence of motion. The Doppler effect occurs when there is relative motion between the source of sound and the receiver of sound, causing a change in the detected frequency of the sound source.

Scattering [221]

Scattering is diffusion or redirection of sound in several directions upon encountering a particle suspension or a rough surface.

Spatial Pulse Length (SPL) [221]

Spatial pulse length (SPL) is the length of space over which a pulse occurs. It is equal to the wavelength times the number of cycles in the pulse (n). Typical units are mm.

SPL = (Number of Cycles in Pulse) x (Wavelength) = nλ

Stiffness [221]

Stiffness is the resistance of a material to compression. As stiffness increases, propagation speed through the medium increases.

Test Object [221]

A test object is a device without tissue-like properties that is designed to measure some characteristic of an imaging system, typically immersed in a phantom.

Transducer [234]

A transducer is a hand-held device that sends and receives a sound wave signal. It changes electrical impulses into sound waves, receives the reflected sound wave, and converts it back into electrical energy.

Turbulent Flow [221]

Turbulent flow is random, chaotic, multidirectional flow of a fluid.

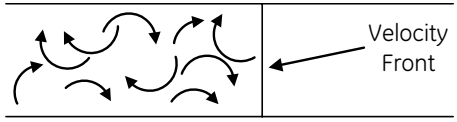


Fig 9.4 – Turbulent Flow

Ultrasound [224]

Ultrasound waves are mechanical waves similar to sound, and must have a medium in which to propagate. Because they exhibit the normal wave properties of reflection, refraction, and diffraction, ultrasound waves, like light beams, can be aimed, focused, and reflected predictably. When reflected, they propagate back, producing echoes that form a sonogram to locate and outline soft tissues and organs. The sound waves are emitted at frequencies above the range of human hearing (20 kHz), and so are called *ultrasound* waves. For diagnostic imaging, frequencies ranging from 2 to 12 MHz are typically used.

Wavelength [221]

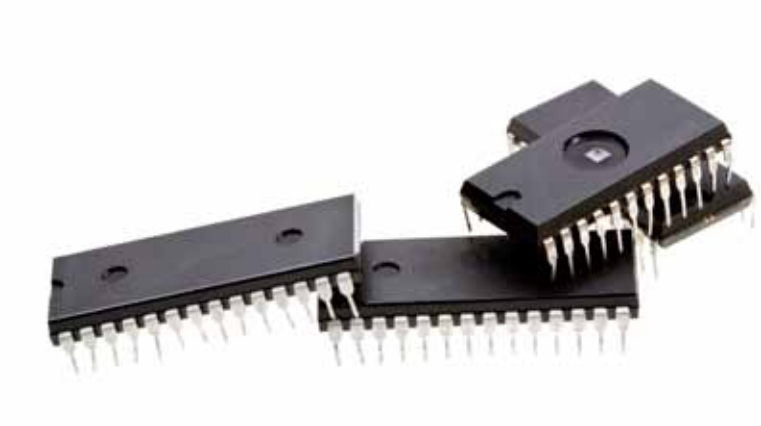
Wavelength (1) is the length of space over which one cycle occurs, and is important when considering image resolution. It is equal to the propagation speed divided by frequency.

$$\text{Wavelength (mm)} = \frac{\text{Propagation Speed (m/s)}}{\text{Frequency (Hz)}} \qquad \lambda = \frac{c}{f}$$

Parameter	Symbol or Abbreviation	Typical Value	Range of Common Values
Frequency	f	3.5 MHz	2-10 MHz
Period	T	0.3 μs	0.1-0.5 μs
Wavelength	λ	0.4 mm	0.1-0.8 mm
Propagation speed	c	1.54 mm/μs	1.4-1.7 mm/μs
Impedance	z	1.63 x 10^6 rayls	3 x 10^6-1.7 x 10^6 rayls
Pulse repetition frequency	PRF	1 kHz	1-10 kHz
Pulse repetition period	PRP	1 ms	0.1-1 ms
Cycles per pulse	n	3	1-5
Pulse duration	PD	1 μs	0.5-3 μs
Spatial pulse length	SPL	1 mm	0.1-1 mm
Duty factor	DF	0.001	0.001-0.01
Spatial peak (temporal average intensity)	I_{SPTA}	1 mW/cm^2	0.01-100 mW/cm^2
Spatial peak (pulse average intensity)	I_{SPPA}	1 W/cm^2	0.01-100 W/cm^2
Attenuation coefficient	a_c	3 db/cm	1-5 db/cm
Half-intensity depth	HID	1 cm	0.3-1 cm

Table 9.5 – Diagnostic Ultrasound Parameters in Tissue [221]

10
Digital Electronics



10 – Digital Electronics

Adder [269]

A logic circuit used to add binary numbers.

Adder, Full [269]

A full adder is a digital device that adds two bits (P and Q) and a carry input (CI), and produces a sum (∑) and carry output (CO).

P	Q	CI	Σ	CO
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Table 10.1 – Full Adder Calculation

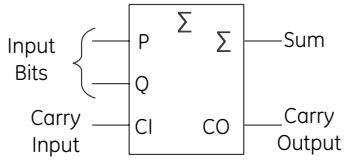


Fig 10.1 – Full Adder

Adder, Half [269]

A half adder is a digital device that adds two bits (P and Q), and produces a sum (∑) and carry output (CO). It cannot handle input carries.

P	Q	∑	CO
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	1

Table 10.2 – Half Adder Calculation

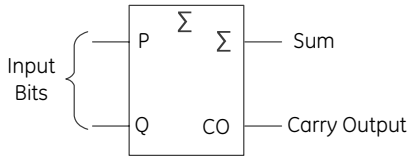


Fig 10.2 – Half Adder

Alphanumeric [269]

Consisting of numerals, letters, and other characters.

AND Gate [269]

The AND gate performs a logical function whose output condition is HIGH only if **all** of its input conditions are HIGH Conversely, its output will be LOW if **any** of its input conditions are LOW.

A	B	$X = \overline{\overline{A} + \overline{B}}$	X = A * B
0	0	0	0
0	1	0	0
1	0	0	0
1	1	1	1

Table 10.3 – AND Gate Calculation

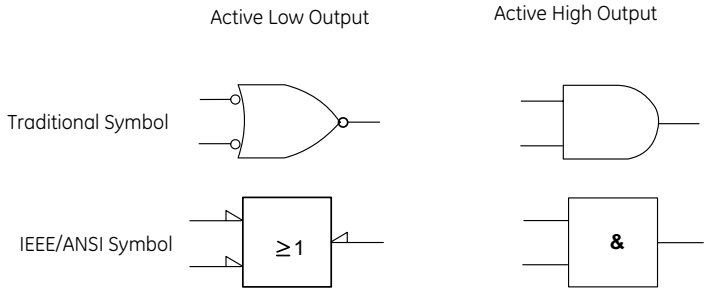


Fig 10.3 – AND Gate

Asynchronous [270]

Operation of a switching network by a free-running signal that triggers successive instructions. The completion of one instruction triggers the next.

ASCII Code [269]

The most widely used alphanumeric code, the American Standard Code for Information Interchange (ASCII). It is a seven-bit code, and is the most widely used input/output code for computers.

LSBs	MSBs							
	000(0)	001(1)	010(2)	011(3)	100(4)	101(5)	110(6)	111(7)
0000(0)	NUL	DLE	SP	0	@	P	`	p
0001(1)	SOH	DC1	!	1	A	Q	a	q
0010(2)	STX	DC2	"	2	B	R	b	r
0011(3)	ETX	DC3	#	3	C	S	c	s
0100(4)	EOT	DC4	$	4	D	T	d	t
0101(5)	ENQ	NAK	%	5	E	U	e	u
0110(6)	ACK	SYN	&	6	F	V	f	v
0111(7)	BEL	ETB	'	7	G	W	g	w
1000(8)	BS	CAN	(	8	H	X	h	x
1001(9)	HT	EM	)	9	I	Y	i	y
1010(A)	LF	SUB	*	:	J	Z	j	z
1011(B)	VT	ESC	+	;	K	[	k	{
1100(C)	FF	FS	,	<	L	\	l	|
1101(D)	CR	GS	-	=	M	]	m	}
1110(E)	SO	RS	.	>	N	↑	n	~
1111(F)	SI	US	/	?	O	_	o	DEL

Table 10.4 – ASCII Codes

Definitions of control abbreviations:

ACK	Acknowledge	GS	Croup separator
BEL	Bell	HT	Horizontal tab
BS	Backspace	LF	Line feed
CAN	Cancel	NAK	Negative acknowledge
CR	Carriage return	NUL	Null
DC1-DC4	Direct control	RS	Record separator
DEL	Delete idle	SI	Shift in
DLE	Data link escape	SO	Shift out
EM	End of medium	SOH	Start of heading
ENQ	Enquiry	SP	Space
EOT	End of transmission	STX	Start text
ESC	Escape	SUB	Substitute
ETB	End of transmission block	SYN	Synchronous idle
ETX	End text	US	Unit separator
FF	Form feed	VT	Vertical tab
FS	Form separator		

Astable [269]

Having no stable state. An astable multivibrator oscillates between two quasistable states.

BCD

See **Binary Coded Decimal**.

Binary Number System [269]

The binary number system is a base-two number system composed of the digits 0 and 1 only. It is the most fundamental number system used by all digital computers.

Binary Coded Decimal [269]

A digital code in which each of the decimal digits, 0 through 9, is represented by a group of four bits.

Bistable [269]

Having two stable states. **Flip-flops** and **latches** are bistable **multivibrators**.

Bit [269]

Abbreviation for binary digit, which can be either a 0 or a 1.

Boolean Algebra [269]

A mathematical system for formulating logical statements with symbols so that problems can be written and solved in a manner similar to ordinary algebra. Any single variable or a function of several variables can have either a 1 or a 0 value. A binary 1 will represent a HIGH level, and a binary 0 will represent a LOW level in Boolean equations.

The complement, or **inverse**, of a variable is represented by a bar over the letter, as $\bar{A}$, and usually is read as A bar or Not A. The logical AND function of two variables is represented either by placing a dot between the two variables, as A • B, or simply by writing the adjacent letters without the dot, as AB. The logical OR function of two variables is represented by a + between the two variables, as A + B.

Boolean Rules [269]

$A + O = A$ $\quad A \bullet O = O$
$A + 1 = 1$ $\quad A \bullet 1 = A$
$A + A = A$ $\quad A \bullet A = A$

$A + \bar{A} = 1$ $\quad A \bullet \bar{A} = 0$

$\bar{\bar{A}} = A$

$A + AB = A$

$A + \bar{A}B = A + B$
$(A + B)(A + C) = A + BC$
$A + B = B + A$ $\quad AB = BA$ $\quad$ Commutative Law
$A + (B + C) = (A + B) + C$ $\quad A(BC) = (AB)C$ $\quad$ Associative Law
$A(B + C) = AB + AC$ $\quad$ Distributive Law

$A + B = \overline{\bar{A}\,\bar{B}}$ $\quad AB = \overline{\bar{A} + \bar{B}}$ $\quad$ Demorgan's Theorems

$\bar{A} + \bar{B} = \overline{AB}$ $\quad \bar{A}\bar{B} = \overline{A + B}$

Buffer [270]

A noninverting member of the digital family that may be used to handle a large fan-out or to convert input and output levels.

Byte [269]

A group of eight bits.

Clock [270]

A pulse generator which controls the timing of switching circuits and memory states, and equals the speed at which the major portion of the computer operates.

CMOS

See **Complementary Metal Oxide Semiconductor**.

CMOS vs TTL Performance [269]

Tchnology Gate	Silicon-Gate CMOS	Metal Std. CMOS	Schottky TTL	Low-pwr Schottky TTL	Schottky TTL	Advanced Low-pwr Schottky TTL	Advanced Schottky TTL
Device series	SN74HC	4000B	SN74	SN74LS	SN74S	SN74ALS	SN74AS
Power dissipation per Gate Static @ 100kHz	2.5nW 0.17mW	1µW 0.1mW	10mW 10mW	2mW 2mW	19mW 19mW	1mW 1mW	8.5mW 8.5mW
Propagation delay time (C_L = 15pF)	8ns	105ns	10ns	10ns	3ns	4ns	1.5ns
Maximum clock frequency (C_L = 15pF)	40MHz	12MHz	35MHz	40MHz	125MHz	70MHz	200MHz
Speed/Power product 100kHz	1.4pJ	11pJ	100pJ	20pJ	57pJ	4pJ	13pJ
Fan-out LS loads Same-series	10 *	4 *	40 10	20 20	50 20	20 20	50 40
Maximum input current (V1 = 0.4V)	≠1µA	-1µA	-1.6mA	-0.4mA	-2.0mA	0.1mA	-0.5mA

* Fan-out is a function of frequency.

Table 10.5 – CMOS vs TTL Performance

Code [269]

A combination of **binary** digits that represents such information as numbers, letters, and other symbols.

Comparator [269]

A digital device that compares the magnitudes of two digital quantities, and produces an output indicating the

relationship of the quantities. In its simplest form, a comparator circuit determines whether two numbers are equal.

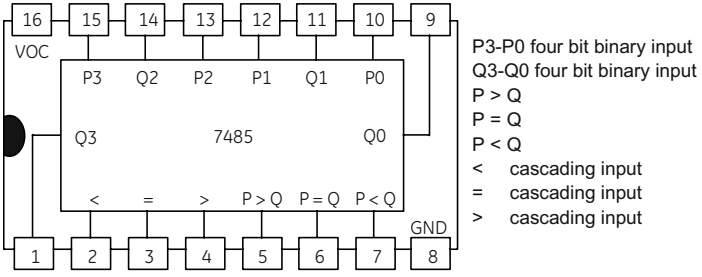


Fig 10.4 – Comparator

Complementary Metal Oxide Semiconductor [269]

A type of transistor circuit which uses field effect transistors.

Counter [270]

A device capable of changing states in a specified sequence on receiving appropriate input signals; a circuit that provides an output pulse or other indication after receiving a specified number of input pulses.

Counter, Asynchronous [269]

An asynchronous counter is a type of counter in which each stage is clocked from the output of the preceding stage.

Counter, Binary [270]

A flip-flop having a single input. Each time a pulse appears at the input, the flip-flop changes states.

Counter, Johnson [270]

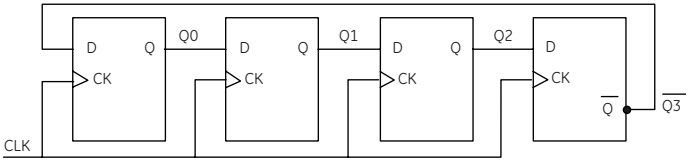


Fig 10.5 – Four-Bit Johnson Counter

Clock Pulse	Q0	Q1	Q2	Q3
0	0	0	0	0
1	1	0	0	0
2	1	1	0	0
3	1	1	1	0
4	1	1	1	1
5	0	1	1	1
6	0	0	1	1
7	0	0	0	1

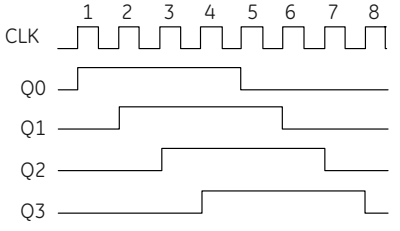


Fig 10.6 – Four-Bit Johnson Sequence

Counter, Ring [270]

A loop or circle of interconnected flip-flops so arranged that only one is on at any given time and that, as input signals are received, the position of the on state moves in sequence from one flip-flop to another around the loop.

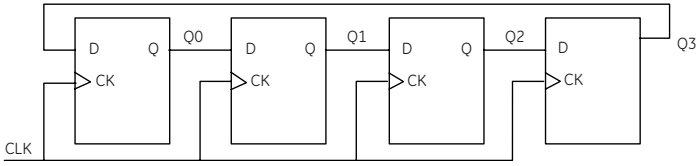


Fig 10.7 – Four-Bit Ring Counter

Clock Pulse	Q0	Q1	Q2	Q3
0	1	0	0	0
1	0	1	0	0
2	0	0	1	0
3	0	0	0	1

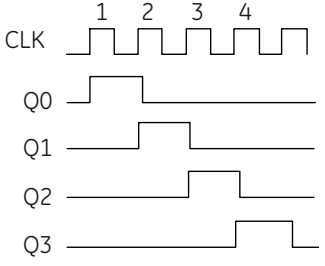


Fig 10.8 – Four-Bit Johnson Sequence

See **Demultiplexer**.

Data Selector

See **Multiplexer**.

DCTL

See **Direct-Coupled Transistor Logic**.

Decoder [269]

A decoder is a digital device that detects the presence of a specified combination of bits (code) on its inputs, and indicates its presence by a specified output level. In general form, a decoder has n input lines to handle n bits and from one to 2^n output lines to indicate the presence of one or more n-bit combinations.

Deci-mal Digit	Binary Inputs				Logic Function	Outputs														
	A_3	A_2	A_1	A_0		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	0	0	0	$\bar{A}3\ \bar{A}2\ \bar{A}1\ \bar{A}0$	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	0	0	0	1	$\bar{A}3\ \bar{A}2\ \bar{A}1\ A0$	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	0	1	0	$\bar{A}3\ \bar{A}2\ A1\ \bar{A}0$	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
3	0	0	1	1	$\bar{A}3\ \bar{A}2\ A1\ A0$	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
4	0	1	0	0	$\bar{A}3\ A2\ \bar{A}1\ \bar{A}0$	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
5	0	1	0	1	$\bar{A}3\ A2\ \bar{A}1\ A0$	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
6	0	1	1	0	$\bar{A}3\ A2\ A1\ \bar{A}0$	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
7	0	1	1	1	$\bar{A}3\ A2\ A1\ A0$	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
8	1	0	0	0	$A3\ \bar{A}2\ \bar{A}1\ \bar{A}0$	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
9	1	0	0	1	$A3\ \bar{A}2\ \bar{A}1\ A0$	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
10	1	0	1	0	$A3\ \bar{A}2\ A1\ \bar{A}0$	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
11	1	0	1	1	$A3\ \bar{A}2\ A1\ A0$	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
12	1	1	0	0	$A3\ A2\ \bar{A}1\ \bar{A}0$	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
13	1	1	0	1	$A3\ A2\ \bar{A}1\ A0$	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
14	1	1	1	0	$A3\ A2\ A1\ \bar{A}0$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
15	1	1	1	1	$A3\ A2\ A1\ A0$	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0

Table 10.6 – Decoding Functions and Truth Table for a 4-Line-to-16-Line Decoder

Delay [270]

Undesirable delay effects are caused by rise time and fall time, which reduce circuit speed, but delay units may be used deliberately to prevent inputs from changing while clock

pulses are present. The delay time is always less than the clock-pulse interval.

Demultiplexer [269]
A (DEMUX) reverses the multiplexing function. It takes data from one line and distributes them to a given number of output lines. This device is also known as a data distributor.

DEMUX
See **Demultiplexer**.

Digital [269]
Related to digits or discrete quantities; having a set of discrete values as opposed to a continuous range of values. Digital electronic levels usually involve two possible states represented by two voltage levels called HIGH and LOW.

Diode-Transistor Logic [270]
Diode-Transistor Logic (DL) is logic performed by diodes. The transistor acts as an amplifier and the output is inverted.

DIP
See **Dual-Inline Package**.

Direct-Coupled Transistor Logic [270]
Direct-coupled transistor logic (DCTL) is logic performed by directly coupled transistor stages.

DTL
See **Diode-Transistor Logic**.

Dual-Inline Package
A type of **IC package** whose leads must pass through holes to the other side of a circuit board.

Encoder [269]
An encoder is a logic circuit that performs a reverse **decoder** function. An encoder accepts an active level on one of its inputs representing a digit, such as a decimal or octal digit, and converts it to a coded output, such as binary or BCD. Encoders can also be devised to encode various symbols and alphabetic characters.

Decimal Digit	BCD Code A3	A2	A1	A0
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

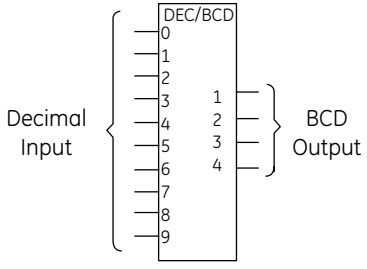


Fig 10.9 – Decimal to BCD Encoder

Excess -3 [269]
An unweighted (no specific weights are assigned to the bit positions) digital code in which each of the decimal digits is represented by a four-bit code derived by adding 3 to the decimal digit and then converting to binary.

Exclusive NOR [268]
The exclusive NOR (EX-NOR} is a Boolean function that is true only when there is an even number of true variables.

A	B	$X = \overline{A \oplus B}$
0	0	-1
0	1	0
1	0	0
1	1	1

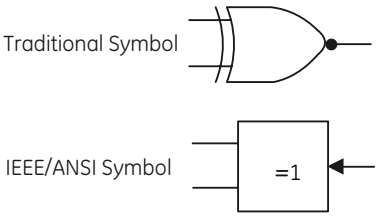


Fig 10.10 – Exclusive NOR

Exclusive OR [268]
The exclusive OR (EX-OR) is a Boolean function that is true only when there is an odd number of true variables.

A	B	X = A ⊕ B
0	0	0
0	1	1
1	0	1
1	1	0

Active High Output

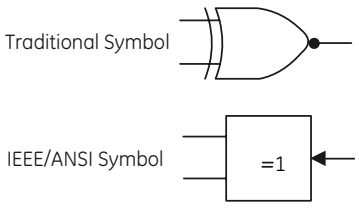


Fig 10.11 – Exclusive OR

Fan-In [270]
The number of inputs available on a gate.

Fan-Out [269]
The number of equivalent gate inputs of the same family series that a logic gate can drive.

Flip-Flop [270]
An electronic circuit having two stable states and the ability to change from one state to the other on application of a signal in a specified manner. Specific types include **D flip-flop**, **J-K flip-flop**, and **T flip-flop**.

Flip-Flop, D [269]
A type of bistable multivibrator in which the output follows the state of the D input.

Input D	Input CK	Outputs Q	Outputs $\overline{Q}$	Comments
0	▲	0	1	RESET
1	▲	1	0	SET

Input D	Input CK	Outputs Q	Outputs $\overline{Q}$	Comments
0	▼	0	1	RESET
1	▼	1	0	SET

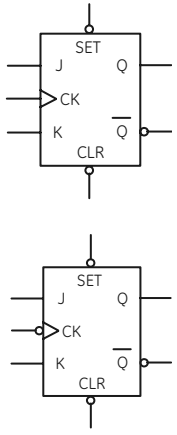


Fig 10.12 – D Flip-Flop

Flip-Flop, Edge-Triggered [269]
A type of **flip-flop** in which the data are entered and appear on the output on the same clock edge.

Flip-Flop, J-K [269]
A type of flip-flop that can operate in the SET, RESET, no change, and toggle modes.

Input J	Input K	Input CK	Outputs Q	Outputs $\overline{Q}$	Comments
0	0	▼	Q_0	$\overline{Q_0}$	No change
0	1	▼	0	1	RESET
1	0	▼	1	0	SET
1	1	▼	$\overline{Q_0}$	Q_0	Toggle

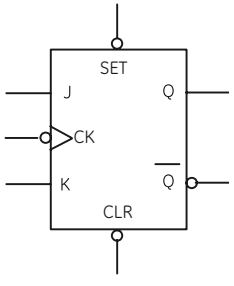


Fig 10.13 – Negative Edge-Triggered J-K Flip-Flop

Input			Outputs		Comments
J	K	CK	Q	$\overline{Q}$	
0	0	⊓	Q_0	$\overline{Q_0}$	No change
0	1	⊓	0	1	RESET
1	0	⊓	1	0	SET
1	1	⊓	$\overline{Q_0}$	Q_0	Toggle

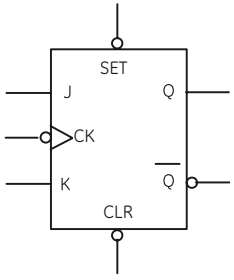


Fig 10.14 – Positive Edge-Triggered J-K Flip-Flop

Flip-Flop, Master-Slave [269]

A type of **flip-flop** in which the input data are entered into the edge on the leading edge of the clock pulse, and appear at the output on the trailing edge.

Gate [269]

A circuit that's output depends on the combination of logic signals at the inputs. Specific logic functions include **AND**, **OR**, **NAND**, **NOR**, and **NOT**.

Gray Code [269]

An unweighted (no specific weights are assigned to the bit positions) digital code characterized by a single bit change between adjacent code numbers in sequence.

Hexadecimal [269]

The hexadecimal number system is a number system with a base of 16, and is a convenient way to express **binary** numbers and codes. It is frequently used in conjunction with computers and **microprocessors** to express binary quantities for input and output purposes and for easy readability.

IC

See **Integrated Circuit**.

IC Packages [271]

A method of enclosing an integrated circuit so that it may be handled and inserted into a circuit. There are many different types of IC packages, including **Dual-Inline Package (DIP)**, **Leadless Ceramic Chip Carrier (LCCC)**, **Plastic-Leaded Chip Carrier (PLCC)**, and **Small-Outline (SOIC)**.

Integrated Circuit [271]

An electronic circuit where all the components are contained on a single semiconductor substrate. The advantage of an integrated circuit is its compact size, preassembled and rested condition, and low power consumption. See also **IC Packages**.

Inverter

See **NOT Gate**.

Large Scale Integration [269]

A level of **IC** complexity in which there are 100-1,000 equivalent gates per chip.

Latch [269]

A latch is a bistable digital device that can reside in either of two states by virtue of a feedback arrangement, in which the outputs are connected back to the opposite inputs.

Input		Outputs		Comments
$\overline{S}$	$\overline{R}$	Q	$\overline{Q}$	
1	1	NC	NC	No change
0	1	1	1	Latch SETS
1	0	0	1	Latch RESETS
0	0	1	1	Invalid condition

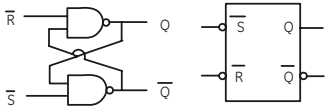


Fig 10.15 – Active-LOW Input S-R Latch

Input		Outputs		Comments
S	R	Q	$\overline{Q}$	
0	0	NC	NC	No change
1	0	1	1	Latch SETS
0	1	0	1	Latch RESETS
1	1	1	1	Invalid condition

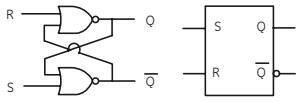


Fig 10.16 – Active-HIGH Input S-R Latch

LCCC
See **Leadless Ceramic Chip Carrier**.

Leadless Ceramic Chip Carrier [269]
A surface-mount technology **IC package** that has metallic contacts molded into its body.

Least Significant Bit [269]
The right-most bit in a binary number or code.

Logic [269]
In digital electronics, the decision-making capability of **gate** circuits, in which a HIGH represents a true statement and a LOW represents a false one.

Logic Gate [251]
A gate performs a logical operation on one or more inputs. The most common gates include **NOT (inverter)**, **AND**, **OR**, **NAND**, **NOR**, **Exclusive OR**, and **Exclusive NOR**.

LSB
See **Least Significant Bit**.

LSI
See **Large-Scale Integration**.

Medium-Scale Integration [269]
A level of IC complexity in which there are 12-100 equivalent gates per chip.

Microprocessor [269]
A **VLSI** device that can be programmed to perform arithmetic, logic, and other operations, and to process data in a specified manner.

Monostable [269]
Having only one stable state. A monostable **multivibrator**, commonly called a **one-shot**, produces a single pulse in response to a triggering input.

Most Significant Bit [269]
The left-most bit in a binary number or code.

MSB
See **Most Significant Bit**.

MSI
See **Medium-Scale Integration**.

Multiplexer [269]
A multiplexer (MUX) is a device that allows digital information from several sources to be routed onto a single line for transmission over that line to a common destination. The basic multiplexer has several data input lines and a single output line. It also has data-detect inputs, which permit digital data on any one of the inputs to be switched to the output line.

Data-Select Inputs		
S1	S0	Input Selected
1	1	D0
0	1	D1
1	0	D2
0	0	D3

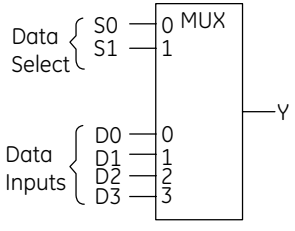


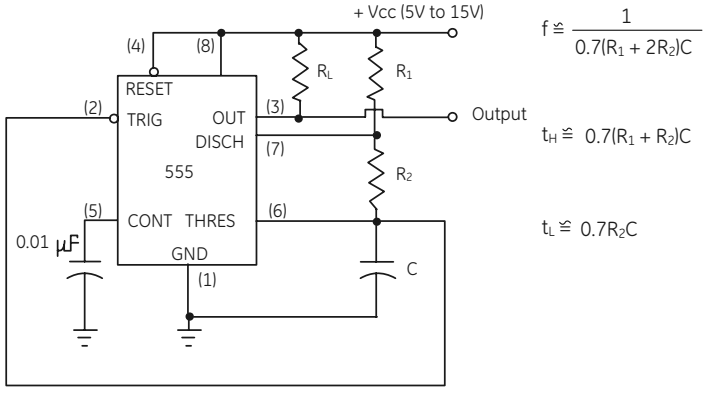
Fig 10.17 – 1-of-4 Data Selector / Multiplexer

Multivibrator [269]

A class of digital circuits in which the output is connected back to the input to produce either two stable states, one stable state, or no stable states, depending on the configuration.

Multivibrator, Astable [269]

A free-running multivibrator with no stable states. The astable multivibrator is typically used as an oscillator to provide clock signals for timing purposes.



$$f \cong \frac{1}{0.7(R_1 + 2R_2)C}$$

$$t_H \cong 0.7(R_1 + R_2)C$$

$$t_L \cong 0.7R_2C$$

Fig 10.18 – Astable Multivibrator

Multivibrator, Monostable

See **One-Shot**.

MUX

See **Multiplexer**.

Number Systems

Decimal	Binary	Octal	HEX	BCD
0	00000	00	00	0000 0000
1	00001	01	01	0000 0001
2	00010	02	02	0000 0010
3	00011	03	03	0000 0011
4	00100	04	04	0000 0100
5	00101	05	05	0000 0101
6	00110	06	06	0000 0110
7	00111	07	07	0000 0111
8	01000	10	08	0000 1000
9	01001	11	09	0000 1001
10	01010	12	0A	0001 0000
11	01011	13	0B	0001 0001
12	01100	14	0C	0001 0010
13	01101	15	0D	0001 0011
14	01110	16	0E	0001 0100
15	01111	17	0F	0001 0101
16	10000	20	10	0001 0110
17	10001	21	11	0001 0111
18	10010	22	12	0001 1000
19	10011	23	13	0001 1001
20	10100	24	14	0010 0000
21	10101	25	15	0010 0001
22	10110	26	16	0010 0010
23	10111	27	17	0010 0011
24	11000	30	18	0010 0100
25	11001	31	19	0010 0101
26	11010	32	1A	0010 0110
27	11011	33	1B	0010 0111
28	11100	34	1C	0010 1000
29	11101	35	1D	0010 1001
30	11110	36	1E	0011 0000
31	11111	37	1F	0011 0001

Table 10.7 – Number Systems

NAND Gate [269]

The NAND gate is logically equivalent to the **NOT-AND** function, and can be used as a **universal gate**; that is, it can

be used to construct an AND gate, an OR gate, an inverter, or any combination of these functions.

A	B	$X = \overline{A \cdot B}$	$X = \overline{A} + \overline{B}$
0	0	1	1
0	1	1	1
1	0	1	1
1	1	0	0

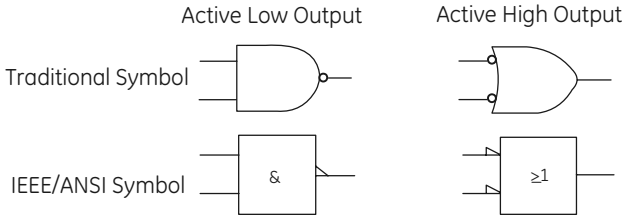


Fig 10.19 – NAND Gate

NOR Gate [268]

The NOR gate is logically equivalent to the **NOT-OR** function, and can be used as **a universal gate**; that is, it can be used to construct an AND gate, an OR gate, an inverter, or any combination of these functions.

A	B	$X = \overline{A + B}$	$X = \overline{A} \cdot \overline{B}$
0	0	1	1
0	1	0	0
1	0	0	0
1	1	0	0

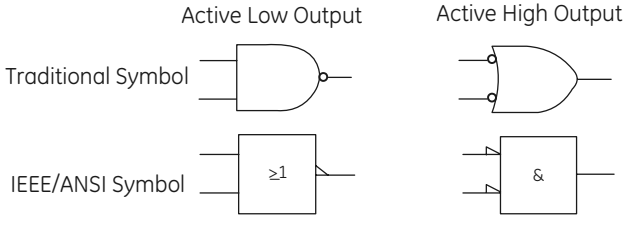


Fig 10.20 – NOR Gate

NOT Gate [269]

The NOT gate (inverter) performs a basic logic function called inversion or complementation. Its purpose is to change one logic level to the opposite level.

A	$X = \overline{A}$
0	1
1	0

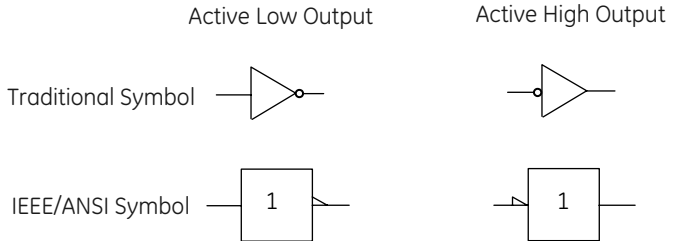


Fig 10.21 – NOT Gate

Octal [269]

The octal number system is a number system with a base of 8, and is a convenient way to express **binary** numbers and codes.

One-Shot [269]

A one-shot is a monostable **multivibrator**. This device has only one stable state. When triggered, if changes from its stable state to its unstable state, and remains there for a specified length of time before returning automatically to its stable state.

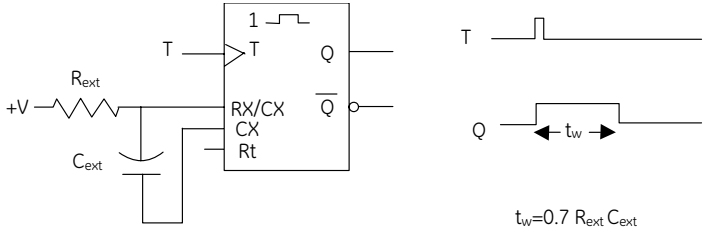


Fig 10.22 – One-Shot / Monostable Multivibrator

OR Gate [269]

The OR gate performs a logical function whose output condition is HIGH if any of its input conditions are HIGH. Conversely, its output will be LOW only if **all** of its input conditions are LOW.

A	B	$X = \overline{\overline{A} \cdot \overline{B}}$	X = A + B
0	0	0	0
0	1	1	1
1	0	1	1
1	1	1	1

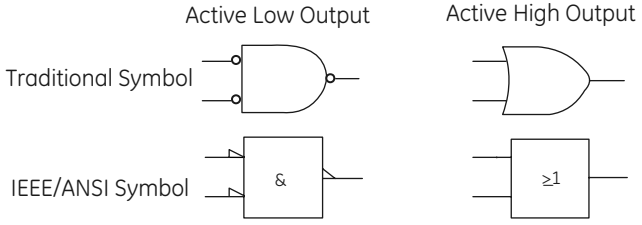


Fig 10.23 – OR Gate

Plastic-Leaded Chip Carrier [269]

A surface-mount technology **IC package** whose leads are turned up under its body in a J-like shape.

PLCC

See **Plastic-Leaded Chip Carrier**.

Power Dissipation [269]

The product of the dc supply voltage and the dc supply current in an electronic circuit.

Powers of Two

2^n	n	2^{-n}
2	1	0.5
4	2	0.25
8	3	0.125
16	4	0.062 5
32	5	0.031 25
64	6	0.015 625
128	7	0.007 812 5
256	8	0.003 906 25
512	9	0.001 953 125
1 024	10	0.000 976 562 5
2 048	11	0.000 488 281 25
4 096	12	0.000 244 140 625
8 192	13	0.000 122 070 312 5
16 384	14	0.000 061 035 156 25
32 768	15	0.000 030 517 578 125
65 536	16	0.000 015 258 789 062 5
131 072	17	0.000 017 629 394 531 25
262 144	18	0.000 003 814 697 265 625
524 288	19	0.000 001 907 348 632 812 5
1 048 576	20	0.000 000 953 674 316 406 25
2 097 152	21	0.000 000 476 837 158 203 125
4 194 304	22	0.000 000 238 418 579 101 562 5
8 388 608	23	0.000 000 119 209 289 550 781 25
16 777 216	24	0.000 000 059 604 644 775 390 625

Table 10.8 – Powers of Two

Printed Circuit [270]

A printed circuit is a pattern comprising printed wiring and printed elements, all formed in a predetermined design in (or attached to) the surface of a substrate.

Propagation Delay Time [269]

The time interval between the occurrence of an input transition and the occurrence of the corresponding output transition.

Race [269]
A condition in a logic network in which the differences in propagation times, through two or more signal paths in the network can produce erroneous output.

Register [270]
A digital device capable of storing a certain number of binary digits. Certain registers may also include provisions for shifting, circulating, or other operations.

RESET [269]
The state of a flip-flop or latch when the Q output is 1.

Resistor-Transistor Logic [270]
Resistor-transistor logic (RTL) is logic performed by resistors. The transistor produces an inverted output from any positive input.

Rise-Time [270]
A measure of the time required for a circuit to change its output from low level (0) to a high level (1).

SET [269]
The state of a flip-flop or latch when the Q output is 0.

Seven-Segment LED Display [269]

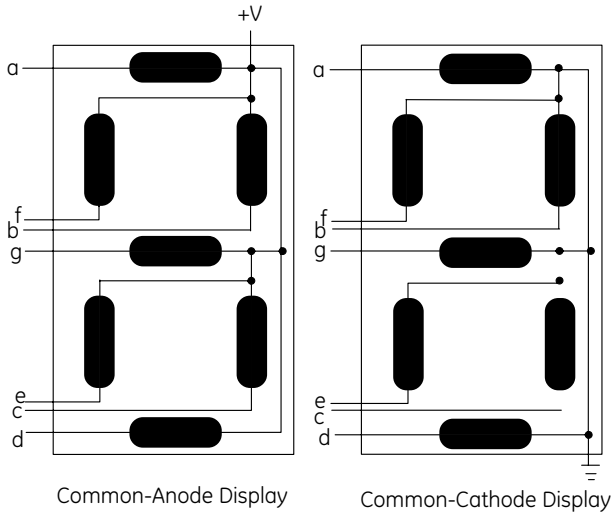


Fig 10.24 – Seven-Segment LED Display

Shift Register [270]
An element in the digital family that uses flip-flops to perform a displacement or movement of a set of digits one or more places to the right or left. If the digits are those of a numerical expression, a shift may be the equivalent of multiplying the number by a power of the base.

Shift Register Counter [269]
A shift register counter is a shift register with the serial output connected back to the serial input to produce special sequences. Two of the most common types of shift register counters include the **Johnson counter** and the **ring counter**.

SMT
See **Surface-Mount Technology**.

Small-Outline Integrated Circuit [269]
A surface-mount technology **IC package** that resembles a small DIP, but has its leads bent out in a gull-wing shape.

Small-Scale Integration [269]
A level of **IC** complexity in which there are 12 or fewer equivalent gates per chip.

SOIC
See **Small-Outline Integrated Circuit**.

Speed-Power Product [269]
A performance parameter that is the product of the propagation delay time and the power dissipation in a digital circuit.

SSI
See **Small-Scale Integration [269]**.

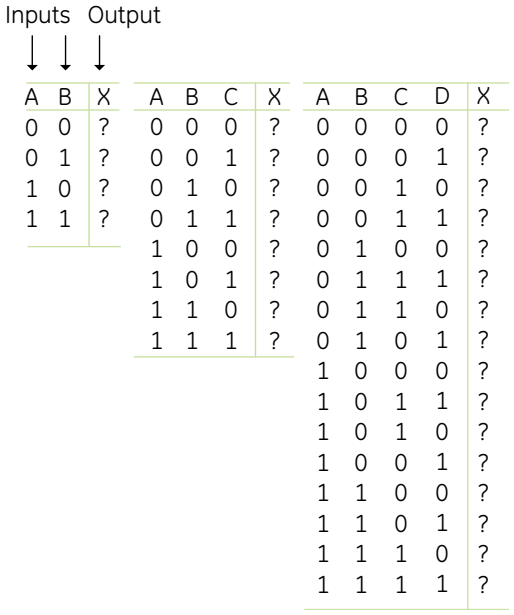
Surface-Mount Technology [269]
An **IC** packaging technique in which the packages are smaller than **DIPs** and are mounted right on the printed circuit board.

Synchronous Timing [270]
Operation of a switching network by a clock pulse generator. Slower and more critical than asynchronous timing, but requires fewer and simpler circuits.

Toggle [269]
The action of a flip-flop when it changes state on each clock pulse.

Transistor-Transistor Logic [269]
Transistor-transistor logic is logic that uses a multiple-emitter bipolar junction transistor.

Truth Table [269]
A truth table is a listing that shows dl the possible input combinations of two-level logic (HIGH and LOW) and the resultant output for a specific logic condition. Truth tables are used in digital electronics to illustrate all possible conditions of a given logic circuit.



A	B	X
0	0	?
0	1	?
1	0	?
1	1	?

A	B	C	X
0	0	0	?
0	0	1	?
0	1	0	?
0	1	1	?
1	0	0	?
1	0	1	?
1	1	0	?
1	1	1	?

A	B	C	D	X
0	0	0	0	?
0	0	0	1	?
0	0	1	0	?
0	0	1	1	?
0	1	0	0	?
0	1	1	1	?
0	1	1	0	?
0	1	0	1	?
1	0	0	0	?
1	0	1	1	?
1	0	1	0	?
1	0	0	1	?
1	1	0	0	?
1	1	0	1	?
1	1	1	0	?
1	1	1	1	?

Fig 10.25 – Truth Table

TTL
See **Transistor-Transistor Logic**.

TTL vs CMOS Performance
See **CMOS vs TTL Performance**.

Unit Load [269]
A measure of **fan-out**. One gate represents a unit load to the output of a gate within the same IC family.

Universal Gates [269]
The term universal gate refers to the property of a gate that permits any logic function to be implemented by that gate or by a combination of gates of that kind. A universal gate is either a NAND gate or a NOR gate.

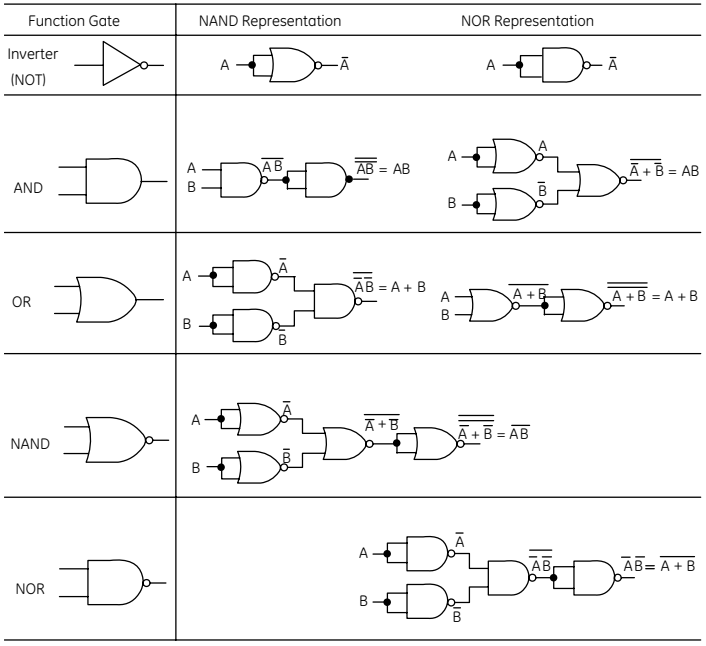


Fig 10.26 – Universal Gates

Very Large-Scale Integration [269]

A level of **IC complexity** in which there are more than 1,000 equivalent gates per chip.

VLSI

See **Very Large-Scale Integration**.

Word [269]

A group of bits representing a complete piece of information.

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11
Defibrillators

11 - Defibrillators

AED
See **Automated External Defibrillators**.

AID
See **Automated Implantable Defibrillators**.

Anteriolateral or Sternum-Apex Position [260]
Most frequently used paddle position for defibrillation. See **Apex Paddle** and **Sternum Paddle** for proper placement.

Anterior-Posterior Position [260]
Paddle position commonly used with disposable electrodes or on neonates when even pediatric paddles may be too large to place both paddles on the anterior chest. See also **Anterior Paddle** and **Posterior Paddle**.

Anterior Paddle [260]
Proper placement of the anterior paddle during anterior-posterior defibrillation is over the patient's cardiac apex just to the left of the sternal border.

Apex Paddle [260]
Proper placement of the apex paddle during anteriolateral defibrillation is on the patient's lower left chest over the cardiac apex, to the left of the nipple in the mid axillary line.

Atrioventricular (AV) Node [260]
Located beneath the endocardium, the AV node transmits electrical impulses to the Bundle of His.

Arrhythmia [265]
Any variation from the normal rhythm of the heartbeat, including sinus arrhythmia, premature beat, heart block, atrial fibrillation, atrial flutter, pulsus atlernans, and paroxysmal tachycardia.

Atrial Fibrillation
See **Fibrillation, Atrial**.

Automated External Defibrillators (AEDs) [264]
An automated external defibrillator is a device that combines the electrodes and output features of the standard external defibrillator with a diagnostic circuit for automatically determining the need to apply a shock.

Automated Implantable Defibrillators (AIDs) [264]
Totally automatic implantable defibrillators resemble pacemakers, but treat tachycardias rather than bradycardias, and have much more powerful electric shock output up to 30J. These devices have been found to greatly reduce mortality in patients who are known to be at very high risk for sudden cardiac death syndrome. The implantable defibrillator contains sensors to detect cardiac activity, a signal processing algorithm for making proper diagnosis of the tachyarrhythmia, and appropriate power supply and energy storage sections. Electrodes are implanted in, on, or near the heart for delivery of the shock. The waveform consists of one or two truncated exponential decay waveforms.

Cardioversion
See **Synchronized Cardioversion**.

Damped Sinusoid Waveform
See **Lown Waveform**.

Defibrillation [265]
Defibrillation is the termination of atrial or ventricular fibrillation, usually by electric shock.

Defibrillator [264]
A defibrillator is a device that is used to apply a strong electrical shock to the heart. The shock changes ventricular fibrillation to an organized ventricular rhythm, or changes a very rapid and ineffective cardiac rhythm to a slower, more effective rhythm.

Depolarization [265]
Depolarization is the reversal of resting potential in excitable cell membranes when stimulated.

Dysrhythmia
See **Arrhythmia**.

Energy, Delivered [260, 264]
Delivered energy (W_D) is the amount of energy actually administered to the patient and is dependent upon the internal impedance of the defibrillator (R_i), and the impedance of the patient (R), particularly the **transthoracic impedance (TTI)**. It can be defined by the equation:

$$W_D = W_S \left(\frac{R}{R + R_i} \right)$$

Energy, Stored [264]
Energy stored (potential energy) in a charged (storage) capacitor is defined by the equation:

$$W_S = \tfrac{1}{2} CV^2$$

where:
W_S is the stored energy in Joules
C is the value of the storage capacitor (Farads)
V is the voltage to which the capacitor is charged (volts)

Fibrillation [234]
Fibrillation is the involuntary recurrent contraction of a single muscle fiber or of an isolated bundle of nerve fibers. Fibrillation of a chamber of the heart results in inefficient random contraction of that chamber and disruption of the normal sinus rhythm of the heart. Fibrillation is usually described by the part that is contracting abnormally, such as atrial fibrillation or ventricular fibrillation.

Fibrillation, Atrial [234]
Atrial fibrillation is a cardiac **dysrhythmia** characterized by disorganized electrical activity in the atria accompanied by a rapid, irregular ventricular response. The atria quiver instead of pumping in an organized fashion, resulting in compromised ventricular filling and reduced stroke volume.

Fibrillation, Ventricular [234]
Ventricular fibrillation is a cardiac **dysrhythmia** marked by rapid, disorganized depolarizations of the ventricular myocardium. The condition is characterized by a complete lack of organized electric impulse, conduction, and ventricular contraction. Blood pressure falls to zero, resulting in unconsciousness, and death may occur within 4 minutes. **Defibrillation** and ventilation must be initiated immediately.

Inherent Rate [260]
The rate of impulse formation in various areas of the conduction system:

Sinus (sinoatrial or SA) node	60 to 100 per minute
Atrioventricular (AV) node	40 to 70 per minute
Ventricles	20 to 40 per minute

Joule
A joule (J) is the SI unit of energy used to define the output of a defibrillator. It is equivalent to 1 watt-second.

Lown Waveform [262]
The Lown waveform is the output waveform of a DC defibrillator developed in 1962 by Dr. Bernard Lown of the Harvard School of Public Health and Peter Bent Bringham Hospital. Also referred to as a damped sinusoid waveform. See also **Testing**, **Output Waveform-Damped Sinusoid**.

Posterior Paddle [260]
Proper placement of the posterior paddle during anterior-posterior defibrillation is on the patient's left posterior chest, beneath the scapula and lateral to the spine.

Sinoatrial (SA or Sinus) Node [260]
The SA node is located in the upper wall of the right atrium, just below the opening of the superior vena cava.

It is considered to be the source of impulses initiating the heartbeat, and is often referred to as the pacemaker of the heart.

Sternum Paddle [260]
Proper placement of the sternum paddle during anteriolateral defibrillation is on the patient's upper right chest, to the right of the sternum below the clavicle.

Sternum-Apex Position
See **Anteriolateral Position**.

Storage Capacitor [185]
An integral component of a defibrillator used to store high D.C. voltage and then rapidly discharge through electrodes attached to the patient.

Synchronized Cardioversion [260, 264]
The delivery of energy to the heart during the phase of ventricular depolarization, or upon the detection of the QRS complex (R-wave). It may be used to treat atrial fibrillation or atrial flutter with ventricular response, and certain atrial, junctional, or ventricular tachycardias.

Test Load (Defibrillators) [185]
Utilized in testing the output of defibrillators. The paddles are placed on metal plates connected to a 50 ohm resistive path. The 50 ohm load simulates that of the torso resistance. Analyzers used for this test register delivered energy in watt-seconds.

Testing, Charge Time and Maximum Energy (10th Charge) [261, 263]
The time to charge to maximum energy should not exceed 15 seconds. The output energy should remain within 4J or 15%, whichever is greater, of the selected energy when discharged into a 50Ω resistive load.

Testing, Energy After 60 Seconds [263]
The delivered energy 60 seconds after charging should be at least 85% of that obtained when the unit is discharged immediately.

Testing, Internal Paddle Energy Limit [261, 263]
The maximum selectable delivered energy, when used with internal paddles, should not exceed 50J.

Testing, Output Energy [261, 263]
At its maximum setting, a defibrillator should be able to deliver at least 250J. The output energy should be within 4J or 15% of the selected energy, whichever is greater, when discharged into a 50Ω resistive load.

Testing, Output Waveform-Damped Sinusoid [261]
The output waveform of a defibrillator delivering a Lown, or damped sinusoid waveform, obtained by discharging a capacitor through a wave shaping coil shall meet the requirements of **Table 11.1** as shown in **Figure 11.1**.

Waveform Parameter	Load Resistance		
	25 Ohms	*50 Ohms*	*100 Ohms*
I_p (amperes)	$96\alpha \geq I_p \geq 55\alpha$	$66\alpha \geq I_P \geq 45a$	$46\alpha \geq I_P \geq 25.1\alpha$
$\|I_R\|$ (amperes)	$38\alpha \geq \|I_R\| \geq 0.0$	$0.018\alpha \geq \|I_R\| \geq 0.0$	$4.0\alpha \geq \|I_R\| \geq 0.0$
t_r (ms)	$1.60 \geq t_r \geq 0.50$	$1.42 \geq t_r \geq 0.40$	$1.25 \geq t_r \geq 0.30$
t_{50} (ms)	$4.60 \geq t_{50} \geq 2.0$	$4.17 \geq t_{50} \geq 2.10$	$6.40 \geq t_{50} \geq 2.30$
t_{10} (ms)	$6.90 \geq t_{10} \geq 3.0$	$9.20 \geq t_{10} \geq 3.10$	$19.60 \geq t_{10} \geq 4.00$

Note:
I_p = Peak current of the waveform
$|I_R|$ = Absolute value of the reverse current of the waveform
α = $\sqrt{E}/360$ and E is the selected energy that would be delivered to a 50Ω resistive load
t_r = 10% to 90% risetime of the first lobe of the current waveform
t_{50} = Waveform width associated with the 50 percentage points of the first lobe of the current waveform
t_{10} = Waveform width associated with the 10 percentage points of the first lobe of the current waveform

Table 11.1 – Specifications for Damped Sinusoid Output Waveforms

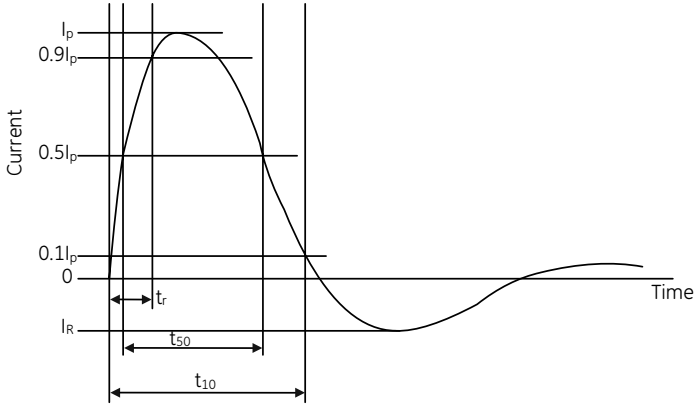

Figure 11.1 – Damped Sinusoidal Waveform Parameters

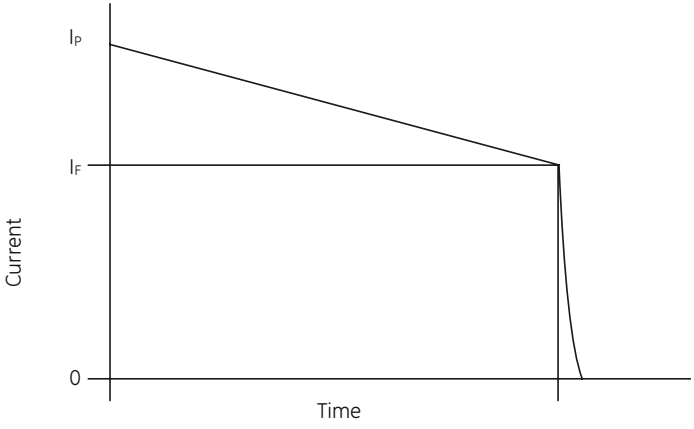

Figure 11.2 – Truncated Exponential Waveform Parameters

Testing, Output Waveform-Truncated Exponential [261]

The output waveform of a defibrillator delivering a truncated exponential waveform obtained by truncating a capacitor discharge shall meet the requirements of **Table 11.2** as shown in **Figure 11.2**.

Waveform Parameter	Load Resistance		
	25 Ohms	*50 Ohms*	*100 Ohms*
I_p (amperes)	80	40	20
t_{max} (ms)	15	24	40
t_{min} (ms)	1	2	3

Note:
I_p = Peak current of the waveform
I_F = Waveform current measured just prior to truncation of the capacitor discharge
t_F = Duration of the waveform measured at IF

Table 11.2 – Specifications for Truncated Exponential Output Waveforms

Testing, Paddle Continuity [263]

The resistance from the paddle to the appropriate pin of the paddle connector should not exceed 0.15Ω.

Testing, Synchronized Cardioversion [261, 263]

The monitor should provide its synchronizing signal within 35ms of the R wave peak. The delay time between the application of the most recent synchronizing signal from the monitor and the discharge should not exceed 25ms. Thus, the overall delay from the defibrillator and monitor should not exceed 60ms.

Relay (Vacuum) [164]

In defibrillators, the vacuum relay is used to transfer energy from the storage capacitor to the paddles contacting the patient. Due to the high energy level that may exceed 400 Joules (with voltages reaching 7,000 VDC), the relay is vacuum sealed to prevent arching.

Transthoracic Impedance [260]

The transthoracic impedance (TTI) is the amount of impedance to current flow across the chest. It is affected by many variables, including the size and placement of the electrodes, the skin-to-paddle interface, the number of and time between previous discharges, the phase of the patient's

ventilation, and the paddle pressure.

Ventricular Fibrillation
See **Fibrillation, Ventricular**.

Watt-Second
See **Joule.**

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12
Infusion Devices

12 – Infusion Devices

Analgesic [234]
An analgesic is a drug that relieves pain.

Anti-Free-Flow Set [291]
Anti-free-flow infusion sets automatically stop flow when the set is removed from the infusion device. They are particularly beneficial when critically ill, fluid restricted patients are treated concentrated potent medications at low flow rates.

Back Pressure [290]
Back pressure is the pressure a solution must overcome to pass through a catheter lumen. Its causes include high viscosity solution, use of a small needle or catheter, and limited fluid container height combined with high infusion rates.

Bolus [234]
A bolus is a dose of medication or a contrast material, radioactive isotope, or other pharmaceutic preparation injected all at once intravenously.

Cassette, Syringe [291]
A pumping mechanism found in infusion pumps that uses a motor-driven plunger moving into and out of a cylinder. The inward motion pumps the fluid out of the cassette toward the patient, while the outward motion draws fresh fluid from the solution container to refill the cassette. In some cassettes, a valve directs the flow along the desired path at the appropriate times in the plunger cycle.

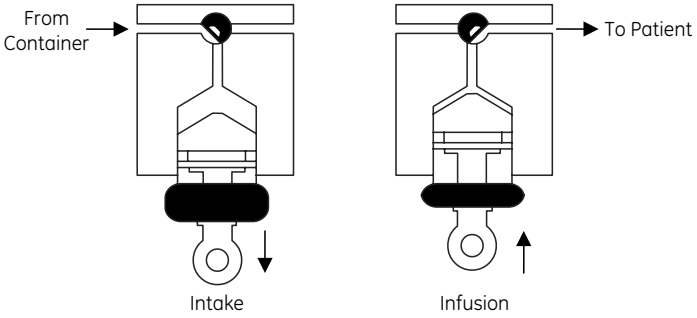

Fig 12.1 – Cassette Pumping Mechanism

Cassette, Piston [291]
A pumping mechanism found in infusion pumps that uses a diaphragm mounted near a moving piston. The piston displaces a fraction of a milliliter of fluid toward the patient with each inward stroke, and allows the diaphragm to refill with each outward stroke. A valve assembly directs the flow along the desired path at the appropriate time in the plunger cycle. This pumping mechanism delivers the infusate in discrete volume increments, normally in a pulsating flow. The flow is automatically controlled by varying the piston stroke length and rate.

Controller
See **Infusion Controller**.

Controller Flow Restricting Mechanisms [290]
There are three basic types of flow-restricting mechanisms used in drop-counting, gravity-fed systems. They include **pincher-anvil device**, **rotary valve cassette**, and **diaphragm drip chamber**. Controllers that measure intravenous solution volumetrically utilize an **optical sensor** or a **volumetric cassette chamber**.

Controller Pressure [290]
The higher the container, the greater the driving force and the higher the potential flow. Each foot of height produces about 25 millimeters of mercury (mmHg) of pressure.

Demand Analgesic Pump
See **Infusion Pump, Patient-Controlled Analgesic**.

Diaphragm Drip Chamber [290]
An infusion controller flow restricting mechanism that uses IV sets with a special drip chamber. A diaphragm partially occludes an inlet orifice at the top of the drip chamber, and the amount of force the controller exerts on the diaphragm determines the flow.

Dry IV [291]
Dry IVs are infusion sets that fill with air once the fluid container empties.

Epidural [234]
Outside or above the dura matter – the outermost and most fibrous of the three membranes surrounding the brain and spinal cord.

Flow Error [291]
A flow error is an alarm that activates if flow deviates significantly from the set delivery rate.

Infusate [234]
A fluid infused into a patient over a specified period of time.

Infusion Controller [290]
Infusion controllers automatically regulate the flow of **intravenous** solutions through a gravity driven system and provide an alternative to flow control through the use of manual clamps.

Infusion Pump [291]
Infusion pumps facilitate accurate and consistent IV administration of potent, fast-acting cardiovascular and other drugs and solutions. They reduce the incidence of some problems common to manually clamped gravity infusion sets, including drop-rate drifts, **runaways**, and **dry IVs**. Infusion pumps are also used to supply higher pressures than those provided by manually clamped gravity infusion sets or controllers.

Infusion Pump, Ambulatory [295]
Ambulatory infusion pumps deliver **parenteral** agents from syringes or collapsible bags and are small enough to be worn or carried by patients. They are used to deliver **intravenous**, **epidural**, and occasionally, arterial infusions. Solutions may be infused continuously (e.g., chemotherapy, total **parenteral** nutrition [TPN], human growth hormone) or intermittently (e.g., antibiotics).

Infusion Pump, Multichannel [291]
Multichannel infusion pumps can simultaneously infuse from and monitor two or more IV lines, and can be substituted for several single-channel infusion pumps that might be used on one patient.

Infusion Pump, Patient-Controlled Analgesic [293]
Patient-controlled analgesic (PCA) pumps deliver a bolus of narcotic **analgesic intravenously**, **subcutaneously**, or **epidurially** when activated by the patient. Patient-controlled analgesia allows safe administration of pain medication as needed by the patient, yet within the limits prescribed by the physician.

Infusion Pump, Syringe [293]
Syringe infusion pumps are used to administer such **intravenous** fluids as hyper alimentation solutions, antibiotics, regional anesthetics, antiarrhythmia medications, and chemotherapeutic agents. While gravity-flow infusions are adequate and cost-effective for administering non-critical, non-viscous fluids, variations in the elasticity of the plastic tubing and in back pressure can alter infusion rates. Syringe pumps ensure highly accurate volume delivery and consistent flow for small volumes (≤ 50mL) of potent pharmacological agents or thick feeding solutions.

Intramuscular [234]
Intramuscular (IM) is pertaining to the interior of muscle tissue, as in intramuscular injection – the introduction of a hypodermic needle into a muscle to administer a medication.

Intravenous [234]
Intravenous (IV) is pertaining to the inside of a vein, as in an injection, infusion, or catheter.

IM
See **Intramuscular**.

IV
See **Intravenous**.

IV Set

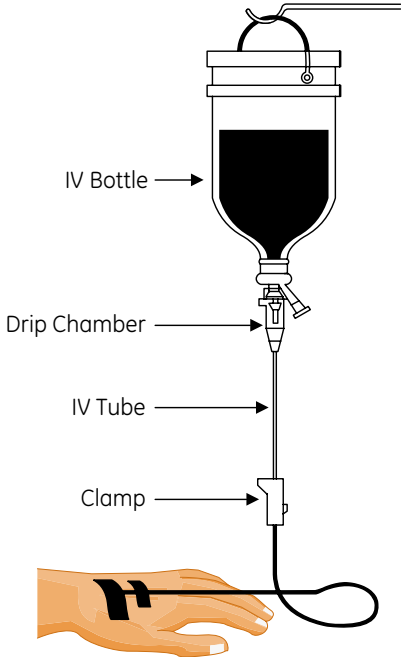

Fig 12.2 – IV Set

Keep-Vein-Open [290]
When the time or volume limit for infusion is attained, some controllers and pumps automatically switch to KVO to prevent the infusion needle from clogging. The KVO rate is always lower than the set infusion rate.

KVO
See **Keep-Vein-Open**.

Loading Dose [292]
The initial bolus dose set by a clinician on a **PCA pump**.

Lockout Interval [292]
To avoid over medication on a **PCA pump**, an adjustable lockout interval inhibits delivery of additional boluses until the appropriate time has elapsed.

Nonabsorbing IV Set [290]
Polyvinyl chloride (PVC), used in most IV set tubing, can absorb medications (e.g., nitroglycerine), therefore, polyethylene sets are used for these types of infusions.

Occlusion [234]
An occlusion is a blockage in a canal, vessel, or passage.

Optical Sensor [290]
An infusion controller volumetric mechanism that uses an optical sensor to measure drop volume, which is then converted to flow rate with a conversion chart.

Parenteral [234]
Not in or through the digestive system.

PCA Pump
See **Infusion Pump, Patient-Controlled Analgesic**.

Peristaltic, Linear [291]
The most common pumping mechanism used in **infusion pumps** is the linear peristaltic type, which uses finger like disks

to occlude the IV tubing successively in a rippling, wavelike motion. The tubing is held against a stationary backing plate, alternately compressed, and released by the moving fingers, forcing the fluid to flow.

Peristaltic, Rotary [291]
A pumping mechanism found in **infusion pumps** that uses a short length of silicon rubber tubing held taught around rollers mounted on a rotor. As the rotor is turned at precise speeds by a motor drive, the rollers occlude the tubing and force the fluid from the solution container into the patient at the preselected rate.

Piggybacking [290]
Most pumps and controllers allow the delivery of a secondary (piggybacked) solution at an infusion rate different from the primary rate. The device automatically switches back to the primary rate when the selected piggybacked volume has been delivered.

Pincher-Anvil [290]
An **infusion controller** flow-restricting mechanism that partially occludes the IV set tubing or intermittently pinches and releases the tubing at a rate that maintains the desired infusion flow. Some controllers that operate according to this principle do not require special IV sets.

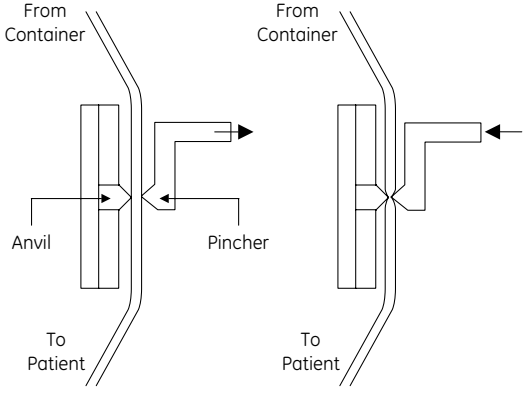

Fig 12.3 – Pincher-Anvil

Prime/Purge Control [293]
A feature of a syringe **infusion pump** that permits priming of the infusion set tubing by momentarily increasing the motor speed. Some clinicians also use this feature to facilitate bolus delivery.

Pump
See **Infusion Pump**.

Pumping Mechanism [291]
General-purpose, microinfusion, and multichannel pumps use one of two basic types of pumping mechanisms to move fluid from the solution container to the patient – **peristaltic** (**linear** or **rotary)** or **cassette** (**syringe** or **piston**).

Rotary Valve Cassette [290]
An **infusion controller** flow restricting mechanism that turns a rotary knob to increase or decrease the size of the valve opening as the controller attempts to maintain the set drop rate. This mechanism requires a dedicated IV set.

Runaways [291]
Runaways are rapid infusions due to dislodged clamps.

Secondary Infusion
See **Piggybacking**.

Subcutaneous [234]
Subcutaneous is beneath the skin, as in a subcutaneous injection – the introduction of a hypodermic needle into the subcutaneous tissue beneath the skin, usually on the upper arm, thigh, or abdomen.

Syringe Pump
See **Infusion Pump, Syringe**.

Testing, Alarm Air-in-Line [294]
Test by introducing a small air bubble into the system by righting the fluid container briefly or by injecting air into

an injection port of the IV tubing with a syringe between the container and the air-in-line detector. Sensitivity to air volumes of less than 50µL is likely to result in nuisance alarms; most devices will trigger an alarm for greater than 100µL air; 50 and 100µL volumes can be approximated by 5 and 10 units, respectively, from a U-100 insulin syringe.

Testing, Alarm-Empty Container [294]

Simulate an empty fluid container while the device is infusing. The simulation method will depend upon the type of sensor employed in the alarm system. For most units, turning the fluid container upright will cut off the supply, empty the tubing leading from the container, and trigger the alarm. For units that rely on a drop sensor or an empty container detector to determine the fluid depletion, simply remove the sensor detector from the drop chamber.

Testing, Alarm-Infusion Complete [294]

If the total volume to be infused can be preset, set it to a low volume (e.g., 10mL) and operate the pump at a high flow setting.

Testing, Alarm-Nurse Call [294]

If the unit has the capability of activating a nurse call system when an alarm condition occurs and it is used in any clinical location, connect the cable and simulate one or more alarm conditions to determine whether they activate the nurse call.

Testing, Alarm-Open Door/Misloaded Infusion Set [294]

Check this alarm during setup and operation.

Testing, Flow Accuracy (Flow ≥ 1mL/hr) [294]

Use an infusion pump analyzer or collect the output in a graduated cylinder. Determine the flow accuracy at two or more typical clinical flow settings (e.g., 10 and 100mL/hr). Use a stopwatch or a watch with a second hand to time the delivery into the graduated cylinder until at least 10mL is collected, and calculate the delivery rate in mL/hr. To calculate flow error:

$$\% \text{ Error} = \frac{\text{Actual Rate - Desired Rate}}{\text{Desired Rate}} \times 100\%$$

Although most intravenous infusion pumps are specified to deliver within 5% of flow setting, 10% is acceptable for most applications. For critical applications, the error should not exceed 5%.

Testing, Flow Accuracy (Flow < 1mL/hr) [294]

If an electronic balance is available, gravimetrically determine the device accuracy by weighing a small beaker (covered with a film of plastic wrap to minimize evaporative losses) before and after collecting a mass of at least 1.5g. Convert the mass to volume (1g H_2O = 1mL). Divide the calculated volume by the time in hours. Follow this procedure to determine the bolus volume accuracy of **PCA pumps**. To calculate flow error:

$$\% \text{ Error} = \frac{\text{Actual Rate - Desired Rate}}{\text{Desired Rate}} \times 100\%$$

Although most intravenous infusion pumps are specified to deliver within 5% of flow setting, 10% is acceptable for most applications. For critical applications, the error should not exceed 5%.

Testing, Maximum Pressure/Occlusion Alarms [294]

Connect the distal end of the primed administration set to a pressure meter and start the infusion. Test alarm pressures at two commonly used flow settings (e.g., 10 and 100mL/hr). If the pressures are outside the unit's specifications, consult the service manual for making the necessary corrections. For units that have adjustable occlusion alarm pressures, test at high and low settings.

Viscosity [234]

Viscosity is the ability or inability of a fluid solution to flow easily. A solution that has high viscosity is relatively thick

and flows slowly because of the adhesive effect of adjacent molecules.

Volume to be Infused [291]

The user programs the volume desired for infusion. When this volume is delivered, most pumps will alarm and revert to a **KVO** rate from the programmed flow setting.

Volumetric Cassette Chamber [290]

An infusion controller volumetric mechanism uses a special valve that controls the filling and emptying of a precisely measured (volumetric) chamber within a cassette attached to the IV set.

VTBI

See **Volume to be Infused**.

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13
Diodes, Rectifiers, Thyristors

13 – Diodes, Rectifiers, Thyristors

Anode [271]
An anode is that part of an electronic device, which is to have a positive voltage applied in relation to its cathode in order to have current flow.

Avalanche Current [273]
The current that occurs when a pn-junction goes into reverse breakdown.

Average Forward Current [273]
The average forward current (Io) rating of a diode is the maximum allowable value of dc current when the device is forward biased.

Barrier Potential [273]
The barrier potential (VB) is the natural difference of potential between the two sides of a pn-junction. The barrier potential is approximately 0.6V for silicon and approximately 0.7V for germanium.

Bias [251]
A device is biased when a voltage is placed across it. Forward bias increases a current that exists prior to attaching the bias voltage; reverse bias decreases or stops an existing current.

Breakdown Voltage [166]
The value of voltage at which breakdown occurs.

Bulk Resistance [266]
The natural resistance of the diode p-type and n-type materials.

Cathode [271]
A cathode is that part of an electronic device, which is to have a negative voltage applied in relation to its anode in order to have current flow.

Clamper [266]
A circuit that adds a dc level to an ac signal.

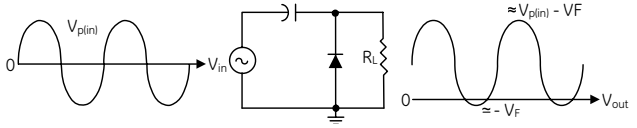


Fig 13.1 – Positive Clamper

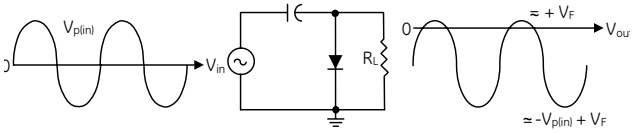


Fig 13.2 – Negative Clamper

Clipper [266]
A clipper or limiter is a diode circuit that clips off or removes part of a waveform above and/or below a specified level. Some basic types of diode clipping circuits are shown.

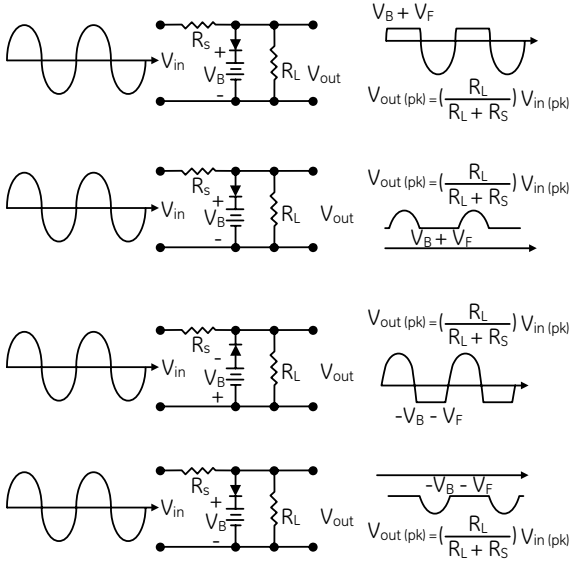


Fig 13.3 – Diode Clipping Circuits

Characteristic Curve
A graph showing the current versus voltage in a diode of transistor.

DC Blocking Voltage
See **Peak Repetitive Reverse Voltage**.

Diac [273]
A diac is a solid-state two-terminal device capable of conducting current in one of two directions when the terminal voltage reaches the breakover potential of the device.

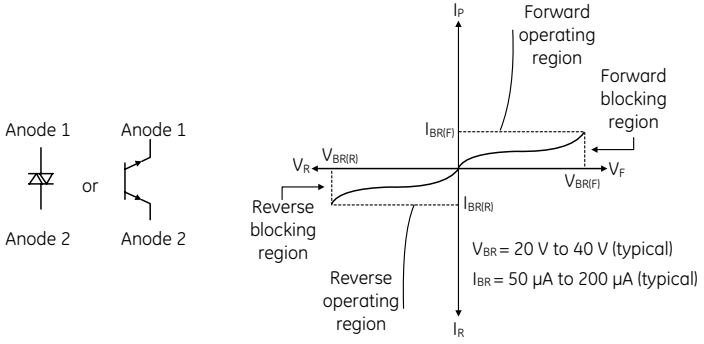


Fig 13.4 – Diac

Diode [273]
A two-terminal device designed to conduct under specific conditions. Among the many types of diodes are **laser**, **rectifier**, **Pin**, **Schottky**, **tunnel**, **zener**, and **photodiode**.

Diode, Hot-Carrier
See **Diode, Schottky**.

Diode, Laser [271]
A solid-state device capable of emitting laser light when electrical energy is applied to it.

Diode, Light-Emitting [273]
Light-emitting Diodes (LEDs) are diodes that will provide a limited amount radiation when forward bias current flows through the pn-junction. Although they are available in several colors (red, green, white, yellow, and orange are the most common), the schematic symbol is the same for all LEDs.

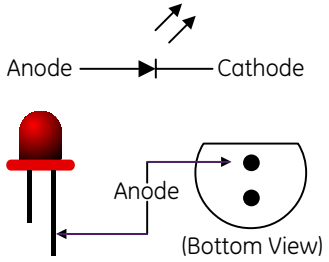


Fig 13.5 – Light-Emitting Diode

LEDs have characteristic curves similar to those for pn-junction diodes. However, they tend to have higher forward voltage (VF) values and lower reverse breakdown voltage (VBR) ratings. The typical range of forward voltage is +1V to +3V, while the typical reverse breakdown voltage is in the range of -3V to -10V. Moreover, because the forward current ratings tend to be lower, usually in the 20mA to 100 mA range, a series current-limiting resistor (RS) is usually required. The value of the limiting resistor can be found by:

$$R_S = \frac{V_{out\,(pk)} - V_F}{I_F}$$

where:
$V_{out\,(pk)}$ = the peak output voltage or the driving circuit
V_F = the minimum forward voltage for the LED
I_F = the maximum forward current for the LED

Multi-color LEDs have also been developed to display three functions with one indicator. It is constructed of a red and green LED, connected in inverse parallel. By reversing the polarity of the applied current, the LED will emit red or green light, while an ac voltage results in a yellow light.

Diode, Pin [271]
A pin diode is a semiconductor that, when reverse biased, exhibits an almost constant capacitance. Usually used as a dc-controlled microwave switch where its resistance can be

controlled by the amount of applied voltage when forward biased, making it a good modulating device.

Diode, Schottky [273]

A Schottky diode has very little junction capacitance. As a result, it can be operated at much higher frequencies than the typical pn-junction diode. The reduced capacitance also results in a much faster switching time, and thus, Schottky devices are being used in more digital switching applications. Schottky diodes typically have lower **forward voltage** (V_F) and breakdown voltage (V_{BR}) values than those of pn-junction diodes; typically on the order of 0.3V and -50V, respectively. In sinusoidal and low-current switching circuits, the Schottky diode is capable of operating at frequencies of 20GHz or more.

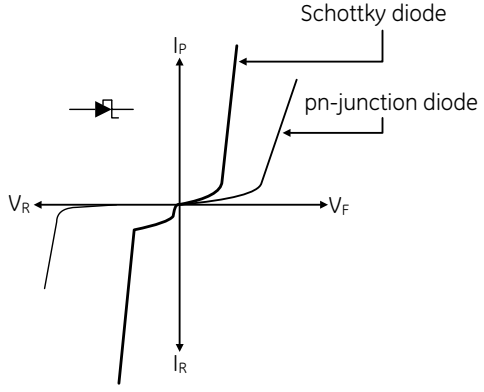


Fig 13.6 – Schottky Diode

Diode, Step-Recovery [271]

A step-recovery diode is a solid-state device with a very fast turn-off time. It is typically used in high-frequency switching applications.

Diode, Rectifier [273]

A rectifier diode is a two-terminal device that acts like a one-way conductor. When forward biased (**cathode** more negative than the **anode**), the device will conduct when reverse biased, diode conduction will drop nearly to zero. The most commonly used semiconductor materials for constructing diodes are silicon and germanium. The **forward voltage** drop across a diode will be approximately 0.7V for silicon and 0.3V for germanium. The characteristic curve for a typical rectifier diode is:

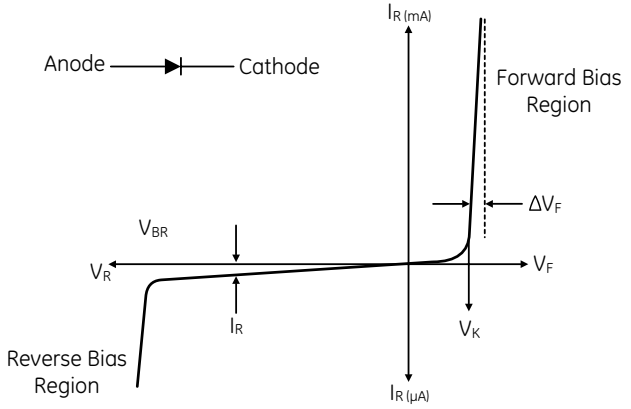


Fig 13.7 – Rectifier Diode

Diode, Tuning

See **Varactor**.

Diode, Tunnel [266]

Tunnel diodes exhibit a special characteristic known as negative resistance. This feature makes them useful in oscillator and microwave amplifier applications.

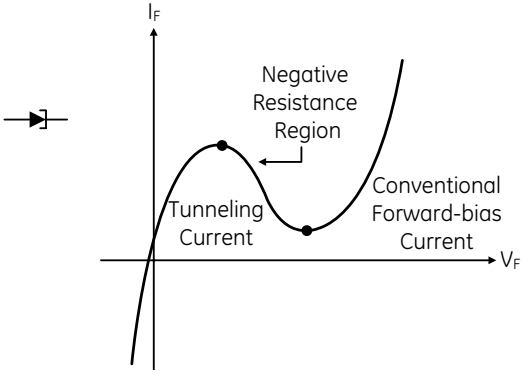


Fig 13.8 – Tunnel Diode

Diode, Varactor [273]

A type of pn-junction diode that has a relatively high junction capacitance when reverse biased. The amount of capacitance varies with the amount of reverse bias, and thus the varactor is most often used as a voltage controlled capacitor. The varactor is also referred to as a varicap, tuning diode, and epicap. The value of the total varactor capacitance (C_T) is inversely proportional to the amount of reverse bias applied to the diode.

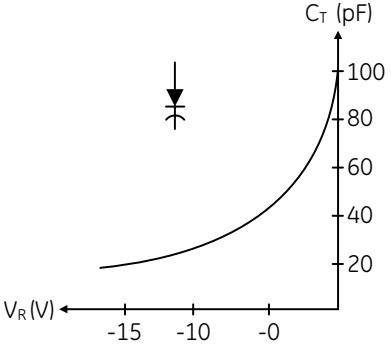


Fig 13.9 – Varactor Diode

Diode, Zener [273]

A zener diode is designed to operate in the reverse breakdown region of the diode curve. In this region, the diode will have a relatively constant voltage across it, regardless of the value of the current through the device. A zener diode will maintain a near-constant reverse voltage, approximately equal to the rated zener voltage (V_Z) specified at the zener test current (I_{ZT}), for a range of reverse current values. The minimum current required to maintain voltage regulation is the zener knee current (I_{ZK}), while the maximum zener current (I_{ZM}) is the maximum amount of current the diode can handle without being damaged.

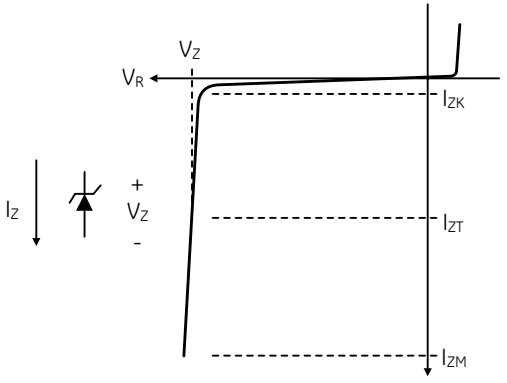


Fig 13.10 – Zener Diode

Epicap

See **Varactor**.

Filter [273]

A circuit that reduces the variations in the output from the rectifier in a dc power supply.

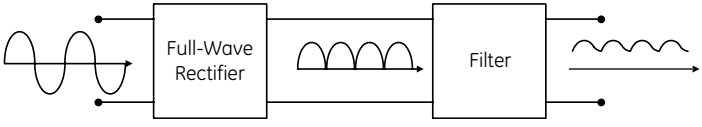


Fig 13.11 – Filter

Filter, Capacitor [273]

This is the most basic filter type and most commonly used. The filtering is based on the charge/discharge action of the capacitor. The value of the dc voltage (V_{dc}) is equal to the peak voltage (V_{pk}) minus one-half of the peak-to-peak value of the **ripple voltage**.

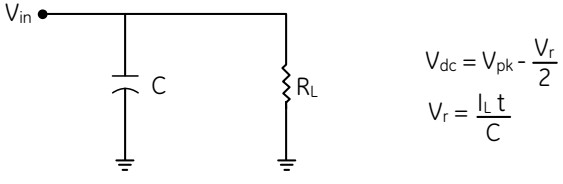
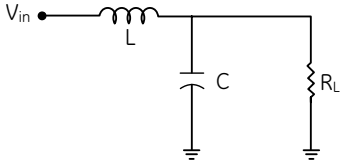


Fig 13.12 – Capacitor Filter

Filter, LC [266]

Adding a choke to the capacitor filter leads to an additional reduction in the **ripple voltage**. The choke has a high reactance at the ripple frequency, and the capacitive reactance is now lowered compared to both XI and RL. The two reactance's form an ac voltage divider that tends to significantly reduce the output ripple.



$$V_{r(out)} = \left(\frac{X_C}{|X_L - X_C|}\right) V_{r(in)}$$

$$V_{dc(out)} = \left(\frac{R_L}{R_W + R_L}\right) V_{dc(in)}$$

where R_W = the choke-winding resistance

Fig 13.13 – LC Filter

Filter, π-Type [266]

In the π-type capacitive-input filter, C_1 charges to the peak value of the input voltage and discharges slightly through the load during the remaining portion of the input cycle. The opposing action of the inductor tends to keep the discharge variation to a minimum, resulting in a relatively small amount of ripple at the output. C_2 also helps to keep the output voltage constant.

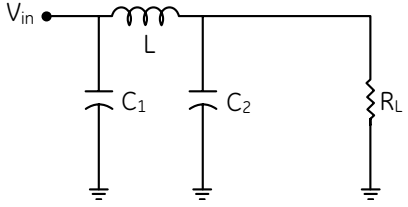


Fig 13.14 – π-Type Filter

Filter, T-Type [266]

In the T-type inductor-input filter, the voltage drop across the reactance reduces the output voltage well below the input peak. However, the smoothing action of L_1 and L_2 tends to provide an output with less ripple than the π-type filter. In general, the T-type filter provides less output voltage for a given input voltage than does the π-type, but it provides improved ripple reduction.

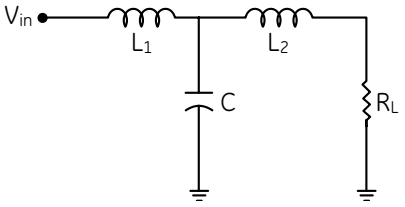


Fig 13.15 – T-Type Filter

Forward Current [273]

Forward current (I_F) is the current that flows through a pn-junction when it is forward biased.

Forward Power Dissipation [273]

The forward power dissipation ($P_{D(MAX)}$) rating indicates the maximum power dissipation of the device when it is forward biased.

Forward Voltage [273]

Forward voltage (V_F) is the voltage across a forward biased pn-junction. The forward voltage will be slightly greater than the barrier potential due to the natural resistance of the device. The values for V_F can be approximated as 0.7V for silicon and 0.3V for germanium.

Junction Capacitance [273]

When a diode is reverse biased, it forms a depletion layer (insulator) between two semiconductor materials (conductors). Therefore, a reverse biased diode forms a small capacitor. This junction capacitance is extremely important when operating under high frequency, but under normal circumstances, it can usually be ignored.

Knee Voltage [273]

Knee voltage (V_K) is the voltage at which device current suddenly increases or decreases.

LED
See **Diode, Light-Emitting**.

Limiter
See **Clipper**.

Peak Inverse Voltage [251]
The peak inverse voltage (PIV) or peak reverse voltage (PRV) is the maximum reverse bias voltage a diode can withstand without deterioration.

Peak Repetitive Reverse Voltage [273]
The peak repetitive reverse voltage (V_{RPM}) indicates the maximum allowable reverse voltage that can be applied to the device. This holds true for both dc and peak ac voltages. This rating is also referred to as the working peak reverse voltage, or the dc blocking voltage.

Peak Reverse Voltage
See **Peak Inverse Voltage**.

Peak Surge Current [273]
Peak surge current (I_{FSM} or I_{TSM}) is the maximum surge (non-repetitive) peak value of forward current that the diode can handle.

Photodiode [267]
A photodiode is a diode whose reverse conduction is light intensity controlled. Radiation falling at the pn-junction will cause a current to flow. The power density of the radiation (measured in m/Wcm^2) determines the current flow. At zero radiation, a small leakage current, called dark current (I_D) will remain.

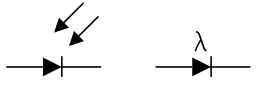


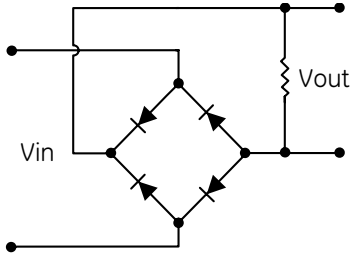
Fig 13.16 – Photodiode

pn-Junction [273]
The boundary between two different types of semiconductor materials. In addition to being essentially a diode, the pn-junction is the basic component of field-effect transistors (FETs) and bipolar junction transistors (BJTs).

Power Derating Factor [273]
The power derating factor (in mW/^{o}C) tells how much the dc power dissipation of a device decreases when the operating temperature increases above a specified value.

Rectifier [273]
A rectifier is a circuit that converts an ac waveform to a pulsing dc waveform. Rectifiers are found in all power supplies that operate from an ac source.

Rectifier, Full-Wave Bridge [251, 266]



$$V_{out(pk)} = V_{in\,(pk)} - 2(V_F)$$

$$V_{ave} = \frac{2V_{out\,(pk)}}{\pi}$$

$$I_{ave} = \frac{V_{ave}}{R_L}$$

$$PIV = V_{out\,(pk)}$$

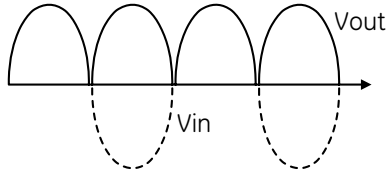
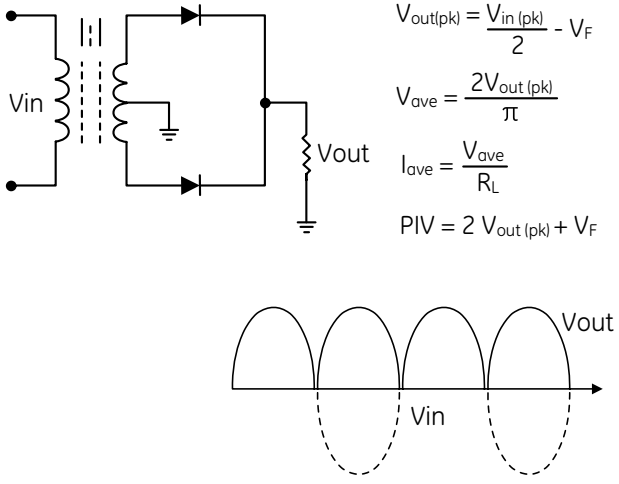


Fig 13.17 – Full-wave Bridge Rectifier

Rectifier, Full-Wave [251, 266]



$$V_{out(pk)} = \frac{V_{in\ (pk)}}{2} - V_F$$

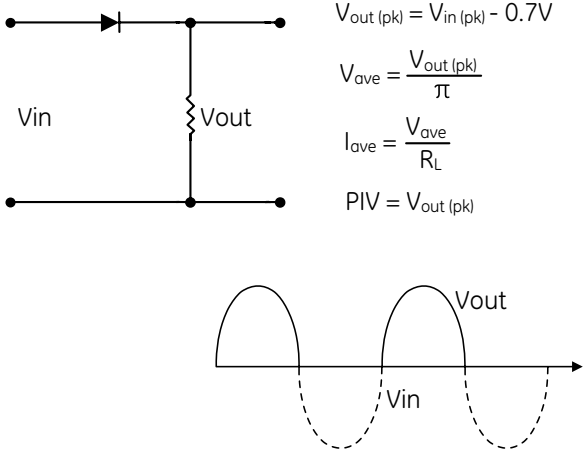
$$V_{ave} = \frac{2V_{out\ (pk)}}{\pi}$$

$$I_{ave} = \frac{V_{ave}}{R_L}$$

$$PIV = 2\ V_{out\ (pk)} + V_F$$

Fig 13.18 – Full-wave Rectifier

Rectifier, Half-Wave [251, 266]



$$V_{out\ (pk)} = V_{in\ (pk)} - 0.7V$$

$$V_{ave} = \frac{V_{out\ (pk)}}{\pi}$$

$$I_{ave} = \frac{V_{ave}}{R_L}$$

$$PIV = V_{out\ (pk)}$$

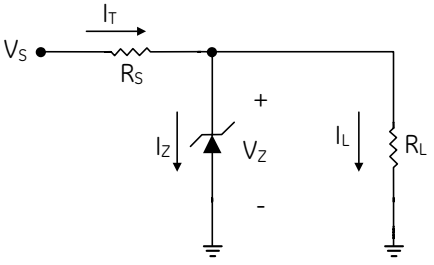
Fig 13.19 – Half-wave Rectifier

Regulator [266]

An electronic device or circuit that maintains an essentially constant output voltage for a range of input voltage or load values.

Regulator, Zener [273]

A **zener diode** operating in the reverse breakdown region will maintain a constant voltage across it as long as the zener current remains between the knee current (I_{ZK}) and the maximum current rating (I_{ZM}). Since the load resistance is in parallel with the zener diode, load voltage will remain constant as long as the zener voltage remains constant.



$$I_Z = I_T - I_L$$

$$I_{L(max)} = I_T - I_{ZK}$$

$$R_{L(min)} = \frac{V_Z}{I_{L(max)}}$$

$$V_{r(out)} = \frac{Z_Z}{Z_Z + R_S} V_r$$

$$R_{S(min)} = \frac{V_S - V_Z}{I_{ZM}}$$

$$R_{S(max)} = \frac{V_S - V_Z}{I_{L(max)} - I_{ZK}}$$

Fig 13.20 – Zener Regulator

Reverse Current [266]

Current flowing on application of a reverse voltage.

Reverse Voltage [266]

In the case of two opposing voltages, the voltage of that polarity which produces the smaller current.

Ripple Factor [266]

The ripple factor (r) is an indication of the effectiveness of the **filter**. The lower the ripple factor, the better the filter. It is defined as:

$$r = \frac{V_r}{V_{dc}}$$

where:
Vr = the rms ripple voltage
Vdc = the dc (average) value of the filter's output voltage

Ripple Voltage [273]

The ripple voltage (Vr) is the peak-to-peak swing of a filtered waveform.

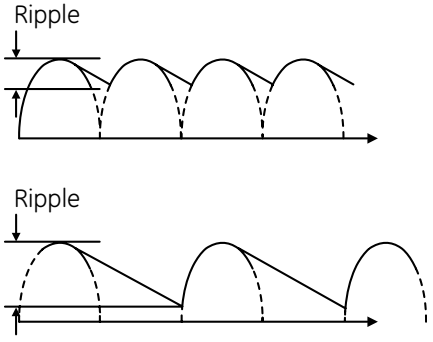


Fig 13.21 – Ripple Voltage

$$Vr = \frac{I_L t}{C}$$

where:
IL = dc load current
C = filter capacitance, in farads
t = time between charging peaks
t @ 16.67ms for H W rectifiers
t @ 8.33ms for FW rectifiers

RMS Reverse Voltage [273]

The rating of a diode found by converting the **peak repetitive reverse voltage** rating to an rms value ($Vrms = 0.707V_{pk}$).

SCR

See **Silicon-Controlled Rectifier**.

Silicon-Controlled Rectifier [273]

A Silicon-controlled Rectifier (SCR) is a three-terminal, unidirectional device similar to the **silicon unilateral switch**. A third terminal, called the gate, provides another means of triggering the device. SCRs were designed primarily for half-wave ac control applications, such as motor controls, heating controls, and power supplies; or wherever half-wave silicon gate-controlled solid state devices are needed.

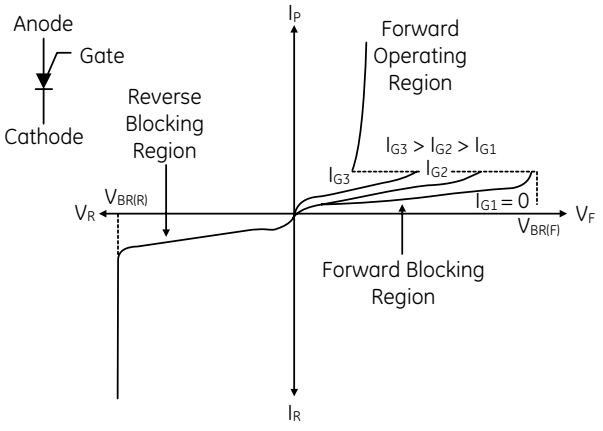


Fig 13.22 – Silicon-controlled Rectifier

Silicon Unilateral Switch [273]

The silicon unilateral switch (SUS) is a **thyristor** that is forced into conduction when the forward voltage across the device reaches a specified forward breakover voltage, $V_{BR(F)}$. Once triggered, the device becomes a low-impedance conductor. It remains in the on state (conducting state) until its forward current (IF) drops below the holding current (I_H) rating of the device. At that time, the device returns to the off state (non-conducting state).

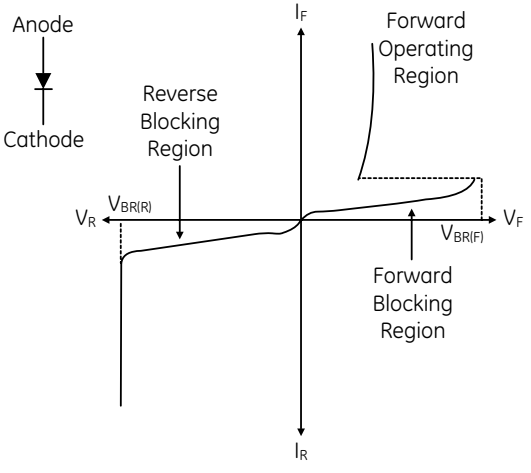


Fig 13.23 – Silicon Unilateral Switch

Static Reverse Current [273]
The static reverse current (IR) is the reverse current through a zener diode, when the reverse voltage (V_R) is less than the zener voltage (V_Z). In other words, this is the leakage current through the diode when it is off.

SUS
See **Silicon Unilateral Switch**.

Thyristors [273]
Devices that are designed specifically for high-power switching applications. Types of Thyristors include the **silicon unilateral switch** (SUS) and the **silicon controlled rectifier** (SCR).

Triac [273]
The triac acts as a bi-directional SCR. The triac can be triggered into conduction by any one of four biasing conditions. Triacs were designed primarily for the control of ac loads in applications such as light dimmers, power supplies, beating controls, motor controls, welding equipment, and power switching systems, or wherever full-wave, silicon gate-controlled solid state devices are needed.

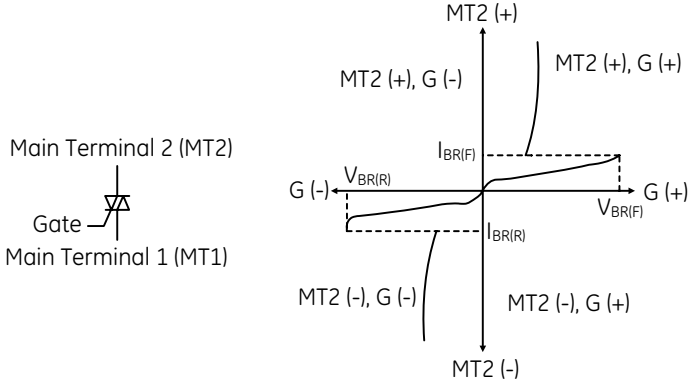


Fig 13.24 – Triac

UJT
See **Unijunction Transistor**.

Unijunction Transistor [266]
A transistor made from a bar of n-type semiconductor with a p-type alloy region on one side. The connections are made to base contacts at either end of the bar and to the p-region.

Varicap
See **Varactor**.

Voltage Multiplier [273]
A circuit that produces a dc output voltage, which is some multiple of its peak input voltage. These circuits use the principle of charging capacitors in parallel from the ac input and adding the voltages across them in series to obtain dc voltages higher than the source voltage.

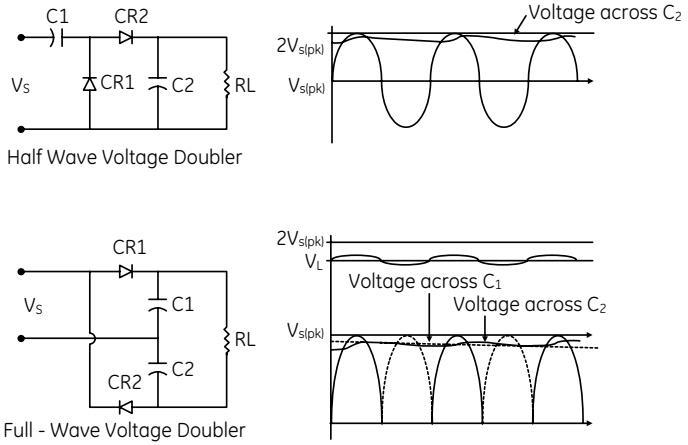


Fig 13.25 – Voltage Multiplier

Working Peak Reverse Voltage
See **Peak Repetitive Reverse Voltage**.

Zener Impedance [273]
The zener impedance (Z_Z) is the zener diode's opposition to a change in current. This value is specified at the zener test current (I_{ZT}) for the device.

14
Transistor Devices and Circuits

14 – Transistor Devices and Circuits

Amplification [266]

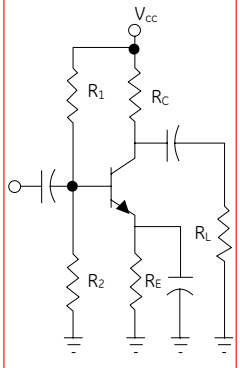
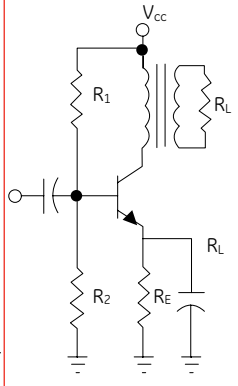
The process of increasing the power, voltage, or current by electronic means.

Amplifier [266]

An electronic circuit having the capability to increase power, voltage, or current.

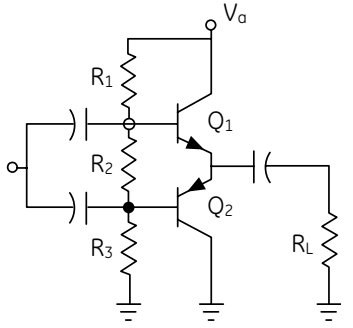
Amplifier, Class A [266, 273]

A class A amplifier is an amplifier that is biased in such a manner that it operates entirely in the linear region of the transistor's characteristic curves. The transistor conducts during the entire input cycle. The maximum theoretical efficiency of a class A amplifier is 25 percent for an RC coupled type, and 50 percent for a transformer coupled type.

Type of Amplifier	RC-Coupled Class A	Transformer-Coupled Class A)
Typical common-emitter circuit		
Compliance (PP)	2VCEQ or 2ICQRC (whichever is less)	VCE(MAX) – VCE(MIN)
Max. theoretical efficiency	25%	50%
Typical efficiency	Less than 10%	Less than 40%

Amplifier, Class B [266, 273]

A class B amplifier is an amplifier that ideally is biased at cut-off so that it operates in the linear region for only 180^0 of its input cycle. Class B amplifiers are more efficient than class A amplifiers, but they are more difficult to implement in the circuit in order to get a linear reproduction of the input waveform. Class B amplifiers are sometimes used in a **push-pull** arrangement on the outputs of audio amplifiers.

Amplifier Type	Class B Complementary-Symmetry	
Schematic Diagram		
Primary dc Relationships	$V_{CEQ} = V_{CC} / 2$	$I_{C(sat)} = V_{CC} / 2R_L$
	ICQ = 0	PS = VCCIC
Primary ac Relationships	$P_L = V_{p\text{-}p2} / 8R_L$	PP = VCC
	$P_{L(max)} = PP^2 / 8R_L$	
Advantage	Higher theoretical efficiency rating (78.5%) than a class A amplifier.	
Disadvantage	Subject to crossover distortion. Requires two transistors to operate.	

Amplifier, Class C [266, 273]

Class C amplifiers are biased so that conduction occurs for much less than 180^0. They are more efficient amplifiers than either class A or push-pull class B, which means that more output power can be obtained from a class C operation. Because the output waveform is severely distorted, class C amplifiers are normally limited to applications as tuned radio frequency (RF) amplifiers.

Amplifier, Common Base [271]

A **bipolar junction transistor** amplifier circuit where the input signal is applied between the emitter and the base, and the output signal is taken from between the collector and the base. Input signal and output signal are in phase. See **Amplifier Configurations, Transistor** and **Bias**.

Amplifier, Common Collector [271]

A **bipolar junction transistor** amplifier circuit, where the collector is electrically common to both the input and output signals. Input signals and output signals are in phase, but the voltage gain is less than 1. Because of the large current gain, this configuration produces a large power gain. Usually referred to as an emitter follower. See **Amplifier Configurations, Transistor** and **Bias**.

Amplifier, Common Drain [271]

A **field effect transistor** amplifier where the drain is electrically common to both the input and output signals. Also referred to as a source follower. See **Amplifier Configuration**, **FET** and **Bias**.

Amplifier, Common Emitter [271]

A **bipolar junction transistor** where the input signal is applied between the base and the emitter, and the output signal is taken from between the collector and the emitter. Input signal and output signal are 180 degrees out of phase. See **Amplifier Configurations, Transistor** and **Bias**.

Amplifier, Common Gate [271]

A **field effect transistor** amplifier where the input signal is applied between the source and the gate, and the output signal is taken between the drain and the gate. See **Amplifier Configuration**, **FET** and **Bias**.

Amplifier, Common Source [271]

A **field effect transistor** amplifier where the input signal is applied between the gate and the source, and the output signal is taken between the drain and the source. See **Amplifier Configuration**, **FET** and **Bias**.

Amplifier, Emitter Follower

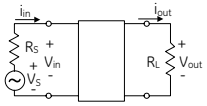
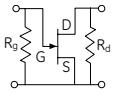
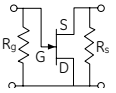
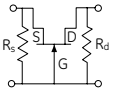
See **Amplifier, Common Collector**.

Amplifier, Source Follower

See **Amplifier, Common Drain**.

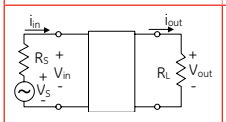
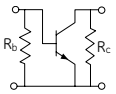
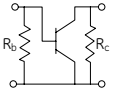
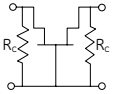
Amplifier Configuration, FET [273]

Comparison of FET amplifier configurations. The current gains and input/output resistances indicate maximum achievable values.

4-Terminal Network	Common Source	Common Drain	Common Gate
			
Voltage Gain A_V	$g_m R_d$	$\frac{R_s}{R_s + \frac{1}{g_m}}$	$g_m R_d$
	Relatively High	< 1	Relatively High
Input Resistance R_{in}	$\left(\frac{V_{GS}}{I_{GSS}}\right) \| R_g \approx R_g$ Very High	$\left(\frac{V_{GS}}{I_{GSS}}\right) \| R_g = R_g$ Very High	$\left(\frac{1}{g_m}\right) \| R_s$ Very Low
Output Resistance R_{out}	$R_d \| 1 / y_{os} \approx R_d$ Relatively High	$R_g \| 1 / g_m$ Very Low	$R_d \| 1 / y_{os} \approx R_d$ Relatively High
Phase Relationship V_{in} vs V_{out}	180° Out-of-Phase	0° In-Phase	0° In-Phase

Amplifier Configuration, Transistor [266]

Comparison of transistor amplifier configurations. The current gains and input/output resistances indicate maximum achievable values.

4-Terminal Network	Common Emitter	Common Collector	Common Base
			
Voltage Gain A_V	R_C / r_C High	1 Low	R_C / r_C High
Max. Current Gain A_i	β_{ac} High	β_{ac} High	1 Low
Power Gain A_p	$A_i A_V$ Very High	A_i High	A_V High
Input Resistance R_{in}	$\beta_{ac} r_e$ Low	$\beta_{ac} R_e$ High	r_e Very Low
Output Resistance R_{out}	R_C Relatively High	$\left(\frac{R_b}{\beta_{ac}} + r_c\right) \| R_E$ Very Low	R_C Relatively High
Phase Relationship V_{in} vs V_{out}	180° Out-of-Phase	0° In-Phase	0° In-Phase

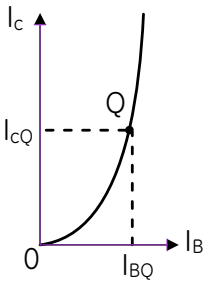
Base [271]

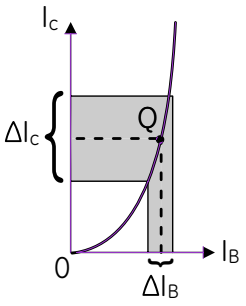
The base is the central part of a bipolar transistor. If is used to help control the current between the **collector** and the **emitter**. See **Bipolar Junction Transistor**.

Beta [266]

Beta (**β**) is the current gain, or the ratio of the collector current to the base current in a bipolar junction transistor. Also referred to as h_{fe}.

$$\beta_{dc} = \frac{I_c}{I_b} \text{ at Q point} \qquad \beta_{ac} = \frac{\Delta I_c}{\Delta I_B}$$



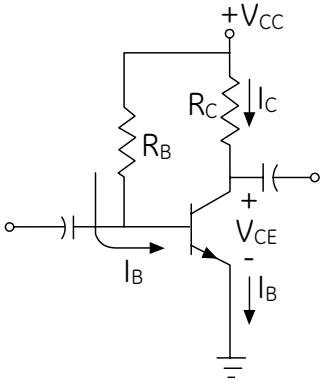


Bias [266]

The application of a small dc voltage to an active device, such as a diode or transistor to produce a desired mode or operation.

Bias (BJT), Base [273]

Base-bias circuits are used primarily in switching applications. While they are easy to build and analyze, the output values are subject to severe Q-point shift, whereby a change in operating temperature causes a change in the Q-point values of IC and V_{CE}.



$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

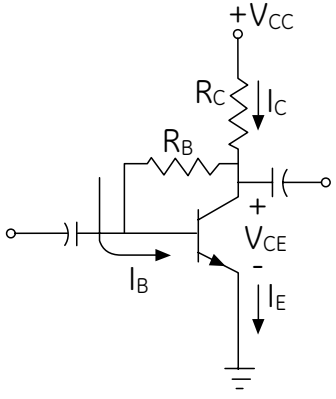
$$I_C = \beta_{dc} I_B$$

$$V_{CE} = V_{CC} - I_C R_C$$

$$V_{CE} = V_{CC} - \beta_{dc} I_B R_C$$

Bias (BJT), Collector-Feedback [273]

In a **transistor** amplifier, collector-feedback bias is a method of establishing the dc **operating point** by connecting the base through a resistor to the collector. This arrangement provides negative feedback to the amplifier.



$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta_{dc} R_C}$$

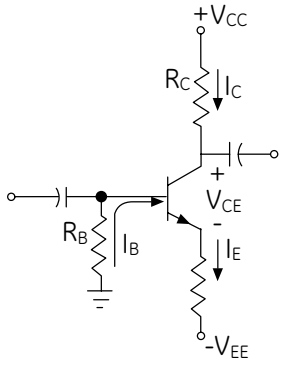
$$I_C = \beta_{dc} I_B$$

$$V_{CE} = V_{CC} - I_C R_C$$

$$V_{CE} = V_{CC} - \beta_{dc} I_B R_C$$

Bias (BJT), Emitter [273]

Emitter-bias circuits are used primarily as a linear amplifier. While the output is basically independent of Beta, the circuit has the disadvantage of requiring a dual-polarity dc power supply.



$$V_B \approx 0$$

$$V_E \approx -V_{BE}$$

$$I_E = \frac{V_E - V_{EE}}{R_E}$$

$$I_C \approx I_E$$

$$V_C = V_{CC} - I_C R_C$$

$$V_{CE} = V_C - V_E$$

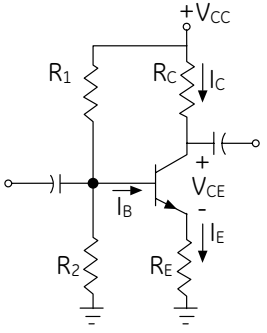
$$I_E = \frac{V_{EE} - V_{BE}}{R_E + \frac{R_B}{\beta_{dc}}}$$

$$I_E = \frac{V_{EE} - V_{BE}}{R_E}, \text{ if } V_{EE} >> \frac{R_B}{\beta_{dc}}$$

$$I_E \approx \frac{V_{EE}}{R_E}, \text{ if } V_{EE} >> V_{BE}$$

Bias (BJT), Voltage-Divider [273]

The voltage-divider bias circuit is the most commonly used. It has the stability of an emitter-bias circuit, while not requiring a split-polarity power supply.



$$R_{IN\,(base)} = \beta_{dc} R_E$$

$$V_B = \left(\frac{R_2 \parallel \beta_{dc} R_E}{R_1 + (R_2 \parallel \beta_{dc} R_E)}\right) V_{CC}$$

$$V_{TH} = V_B \approx \left(\frac{R_2}{R_1 + R_2}\right) V_{CC}, \text{ if } \beta_{dc} R_E \gg R_2$$

$$V_E = V_B - V_{BE}$$

$$I_E = \frac{V_E}{R_E}$$

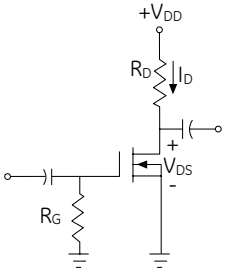
$$I_C \approx I_E$$

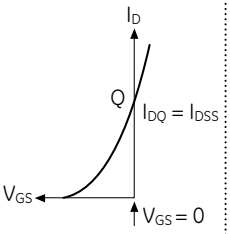
$$V_{CE} \approx V_{CC} - I_E (R_C + R_E)$$

$$I_E = \left(\frac{V_{TH} - V_{BE}}{R_E}\right), \text{ if } R_E \gg \frac{R_{TH}}{\beta_{dc}}$$

Bias (D-MOSFET), Zero [273]

Zero biasing is a method of biasing a **depletion mode MOSFET** that puts the value of gate-to-source voltage (V_{GS}) at 0 V. This biases the amplifier at a drain current of $I_D = I_{DSS}$.





Transconductance Curve and dc Load Line

$V_G = 0$

$V_{GS} = 0$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)$

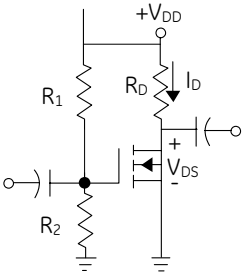
$V_{DS} = V_{DD} - I_D R_D$

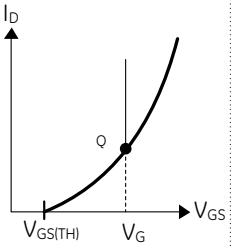
$g_{mo} \simeq \frac{-2I_{DSS}}{-V_{GS(off)}}$

$g_{mo} \approx g_{mo}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)$

Bias (E-MOSFET), Auto [266]

Auto biasing or voltage-divider biasing is a method of biasing an enhancement mode MOSFET to make the gate voltage more positive than the source by an amount exceeding $V_{GS(TH)}$.





Transconductance Curve and dc Load Line

$V_G = V_{DD}\left(\frac{R_2}{R_1 + R_2}\right)$

$V_{GS} = V_G$

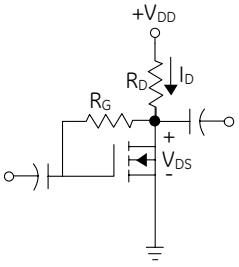
$I_D = K[V_{GS} - V_{GS(TH)}]^2$

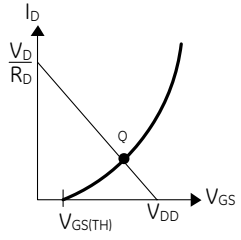
$V_{DS} = V_{DD} - I_D R_D$

$gm = 2\sqrt{K\ I_D}$

Bias (E-MOSFET), Drain-Feedback [273]

In an **enhancement mode MOSFET** amplifier, drain-feedback bias is a method of establishing the dc **operating point** by connecting the gate through a resistor to the drain. This arrangement provides negative feedback to the amplifier.





Transconductance Curve and dc Load Line

$I_D = 0$

$V_G = V_D$

$V_{GS} = V_{DS}$

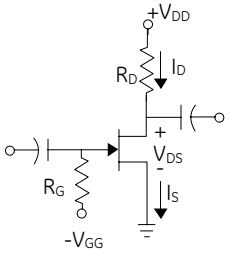
$I_D = K[V_{GS} - V_{GS(TH)}]^2$

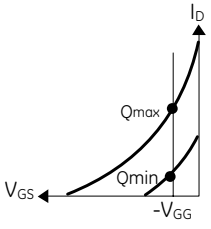
$V_{DS} = V_{DD} - I_D R_D$

$g_m = 2\sqrt{KI_D}$

Bias (FET), Gate [273]

Gate biasing is a method of **field effect transistor** biasing where the gate supply ($-V_{GG}$) is used to ensure that the gate-source junction is reverse biased. This is the preferred type of biasing for many switching applications.





Transconductance Curve and dc Load Line

$V_{GS} = V_{GG}$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$

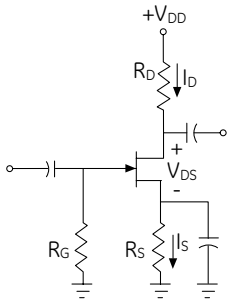
$V_{DS} = V_{DD} - I_D R_D$

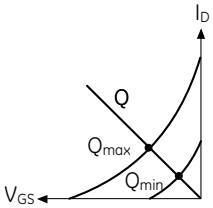
$g_{ma} \approx \frac{-2I_{DSS}}{V_{GS(off)}}$

$g_m \approx g_{ma}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)$

Bias (FET), Self [273]

Self bias is a type of **field effect transistor** biasing that uses a source resistor to establish a negative V_{GS}.





Transconductance Curve and dc Load Line

$V_G = 0$

$I_D = -\frac{V_{GS}}{R_S}$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$

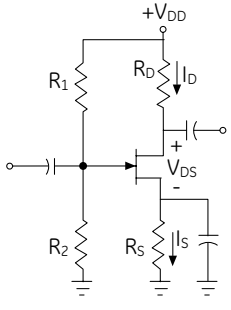
$V_{DS} = V_{DD} - I_D(R_D + R_S)$

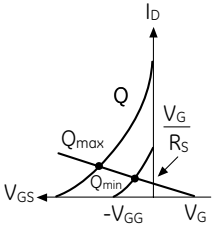
$g_{mo} \simeq \frac{-2I_{DSS}}{V_{GS(off)}}$

$g_{mo} = g_{mo}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)$

Bias (FET), Voltage-Divider [273]

Voltage divider bias is the most stable method of biasing a **field effect transistor** amplifier. The voltage at the source of the FET must be more positive than the voltage at the gate in order to keep the gate-source junction reverse-biased.





Transconductance Curve and dc Load Line

$V_G = \left(\frac{R_2}{R_1 + R_2}\right) V_{DD}$

$I_D = \frac{V_G - V_{GS}}{R_S}$

$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$

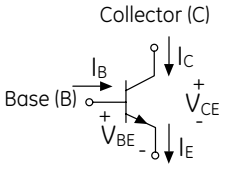
$V_{DS} = V_{DD} - I_D(R_D + R_S)$

$g_{mo} \simeq \frac{-2I_{DSS}}{V_{GS(off)}}$

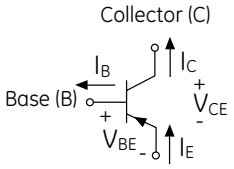
$g_{mo} \approx g_{mo}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)$

Bipolar Junction Transistor [266]

A bipolar junction transistor (BJT) is a device constructed with three doped semiconductor regions separated by two pn junctions. The three regions are called the **emitter**, **base**, and **collector**. There are two types of bipolar transistors; one type consists of two n regions separated by a p region (npn), and the other consists of two p regions separated by an n region (pnp).



npn transistor



pnp transistor

$I_E = I_C + I_B$

$\beta_{dc} = \frac{I_C}{I_B}$

$\alpha_{dc} = \frac{I_C}{I_E} \approx 1$

$I_E \approx I_C$

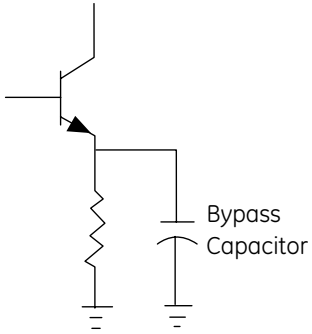
$V_{BE} = 0.7V$

BJT

See **Bipolar Junction Transistor**.

Bypass Capacitor [273]

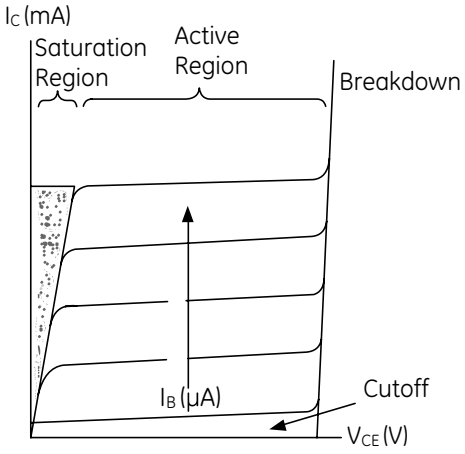
A capacitor that is used to establish an ac ground at a specific point in a circuit.



Collector Curves [273]

The transistor collector curve relates the values of IC, IB, and VCE. The curve is divided into three regions. The saturation region of the curve is the part of the curve where VCE is less than the knee voltage. From the knee voltage to the breakdown region is the active region. This is the region of

operation most commonly used. Above the active region is the breakdown region.



Collector [271]

The collector is the part of a **bipolar junction transistor** that is designed for power dissipation.

Compliance [273]

Compliance (PP) is the maximum peak-to-peak output voltage of an amplifier.

Cutoff [271]

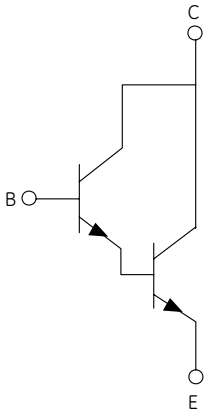
Cutoff is the condition in a current controlling device such as a vacuum tube, transistor, or FET when the controlled current is prevented from flowing in the device. See also **saturation**.

D-MOSFET

See **Depletion Mode MOSFET**.

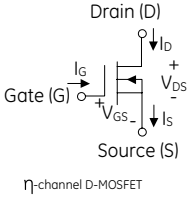
Darlington Pair [271]

A darlington pair is a transistor configuration consisting of an arrangement of two transistors where the collector of one is connected directly to the base of the other. It gives a very high input impedance and high current gain.

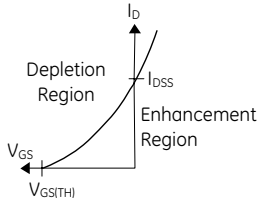


Depletion Mode MOSFET [266]

The depletion mode MOSFET (D-MOSFET) can be operated in either of two modes – the depletion mode or the enhancement mode – and is sometimes called a depletion/enhancement MOSFET. Since the gate is insulated from the channel, either a positive or negative gate voltage can be applied. The D-MOSFET operates in the depletion mode when a negative gate-to-source voltage (V_{GS}) is applied, and in the enhancement mode when a positive gate-to-source voltage is applied.



n-channel D-MOSFET



$I_G = 0$

$I_D = I_S$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$$

$$g_{mo} \approx \frac{-2\,I_{DSS}}{V_{GS(off)}}$$

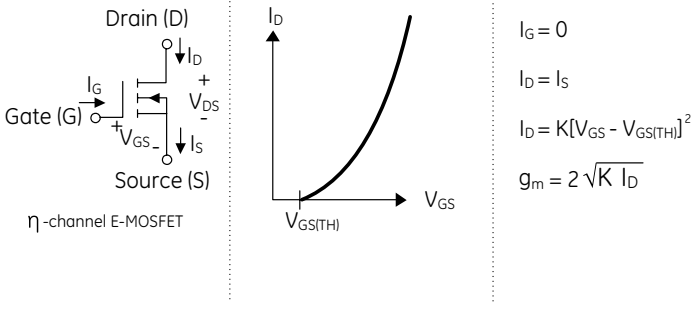
$$g_m \approx g_{mo}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)$$

E-MOSFET

See **Enhancement Mode MOSFET**.

Enhancement Mode MOSFET [266]

The enhancement mode MOSFET (E-MOSFET) operates only in the enhancement mode and has no depletion mode. For an n-channel device, a positive gate-to-source voltage (V_{GS}) above a threshold value ($V_{GS(TH)}$) induces a channel by creating a thin layer of negative charges in the substrate region adjacent to the SiO_2 layer. The conductivity of the channel is enhanced by increasing the gate-to-source voltage, and thus pulling more electrons into the channel.



FET

See **Field Effect Transistor**.

Field-Effect Transistor [271]

A field effect transistor (FET) is a solid-state device consisting of a source, gate, and drain. Voltage applied to the gate controls the current between the source and the drain. There are two basic types of FETs – the **junction field effect transistor (JFET)**, and the **metal oxide semiconductor field effect transistor (MOSFET)**.

Gain [271]

The gain (A) of an amplifier is the ratio of the output value of an electrical quantity to the input value of that same quantity.

Gain, Current [271]

Current gain (Ai) is the ratio of the output current (Iout) to the input current (Iin) of a device; expressed as $\frac{Ai = I_{out}}{I_{in}}$.

Gain, Power [271]

Power gain (Ap) is the ratio of the output power (Pout) to the input power (IPn) of a device, expressed as $\frac{Ap = P_{out}}{P_{in}}$.

Gain, Voltage [271]

Voltage gain (Av) is the ratio of the output voltage (Vout) to the input voltage (Vin) of a device; expressed as $\frac{Av = V_{out}}{V_{in}}$.

Gate [271]

The gate is the conducting lead of a **field effect transistor**, consisting of a source and a drain. The voltage applied to the gate controls the current between the source and the drain.

h-Parameters [266]

Hybrid parameters, or h-parameters, are **transistor** specifications that describe the component operating limits under certain circumstances. They are derived from ac measurements taken from operating transistor characteristic curves, and are used in circuit analysis applications. h-parameters are usually specified on manufacturers' data sheets.

h-Parameter	Description	Common Emitter	Common Base	Common Collector
h_i	Input impedance with short-circuit output	$h_{ie} = \frac{V_b}{I_b}$	$h_{ib} = \frac{V_e}{I_b}$	$h_{ic} = \frac{V_b}{I_b}$
h_r	Reverse open-circuit voltage amplification factor	$h_{re} = \frac{V_b}{V_c}$	$h_{rb} = \frac{V_e}{V_c}$	$h_{rc} = \frac{V_b}{V_e}$
h_f	Forward short-circuit current amplification factor	$h_{fe} = \frac{I_c}{I_b}$	$h_{fb} = \frac{I_c}{I_e}$	$h_{fc} = \frac{I_e}{I_b}$
h_O	Output admittance with open circuit input	$h_{oe} = \frac{I_c}{V_c}$	$h_{ob} = \frac{I_c}{V_c}$	$h_{oc} = \frac{I_c}{V_c}$

Table 14.1 – h-Parameter Ratios for the Three-Amplifier Configurations

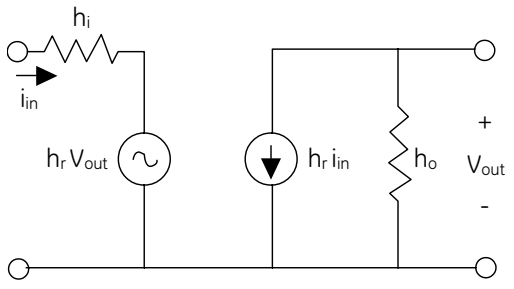
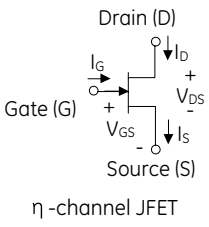


Fig 14.1 – Generalized h-Parameter Equivalent Circuit for a Bipolar Junction Transistor

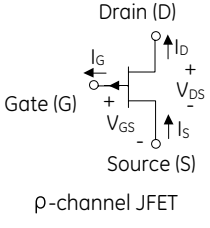
Hybrid Parameters
See **h-Parameters**.

JFET
See **Junction Field Effect Transistor**.

Junction Field Effect Transistor [266]
The junction field effect transistor (JFET) is a type of FET that operates with a reverse-biased junction to control current in a channel. Depending on their structure, JFETs fall into two categories, n-channel to p-channel. The JFET is always operated with the gate-source pn junction reverse-biased.



η -channel JFET



ρ-channel JFET

$I_G = 0$

$I_D = I_S$

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$$

$$g_{mo} \approx \frac{-2\,I_{DSS}}{V_{GS(off)}}$$

$$g_m \approx g_{mo}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)$$

Load Line [271]
The load line is used as part of the graphical analysis of an amplifier. A load line represents a line drawn on the voltage-current characteristics of the amplifier and shows the relationship between the controlling voltage or current, and the resulting voltage or current for the amplifier and external components used with it.

Metal Oxide Semiconductor FET [273]
The metal oxide semiconductor field effect transistor (MOSFET) differs in construction from the **field effect transistor** (FET) in that the MOSFET's gate is insulated from the channel by a layer of silicon dioxide (SiO2). There are two basic types of MOSFETs – depletion-type MOSFET (D-MOSFET) and enhancement-type MOSFET (E-MOSFET).

MOSFET
See **Metal Oxide Semiconductor FET**.

Operating Point
See **Q-point**.

Pinchoff [271]
In a **field effect transistor**, pinchoff (V_p) is the amount and polarity of voltage applied to the gate that will cause drain current to become zero.

PP
See **Compliance**.

Push-Pull Amplifier [271]
A push-pull amplifier consists of two amplifier stages that operate on different half cycles of an input signal. Each amplifier operates on a 180^0 phase difference of the input signal.

Q-Point [271]
The Q-point (quiescent point) is the dc operating point of an amplifier. It is established by external circuit components, and characterizes the class of operation of the amplifier.

Quiescent [271]

At rest. The circuit condition when no input signal is being applied. Power is, however, still applied to the circuit.

r-Parameters [273]

r-Parameter	Description	h-parameter equivalent
α_{ac}	$\frac{I_c}{I_e}$	h_{fb}
β_{ac}	$\frac{I_c}{I_b}$	h_{fe}
r_e	ac Emitter Resistance	$\frac{h_{re}}{h_{oe}} \approx \frac{25mV}{I_E}$
r_b	ac Base Current	$h_{ie} \frac{h_{re}}{h_{oe}}(1+h_{fe})$
r_c	ac Collector Resistance	$\frac{h_{re}+1}{h_{oe}}$

Table 14.2 – r-Parameters

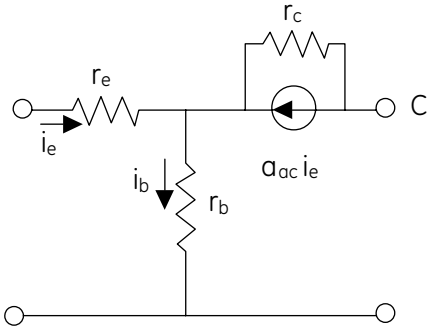


Fig 14.2 - Generalized r-Parameter Equivalent Circuit for a Bipolar Junction Transistor

Saturation [271]

Cutoff is the condition in a current controlling device such as a vacuum tube, transistor, or FET when the controlled current is at its maximum and is limited only by external circuit elements. See also **cutoff**.

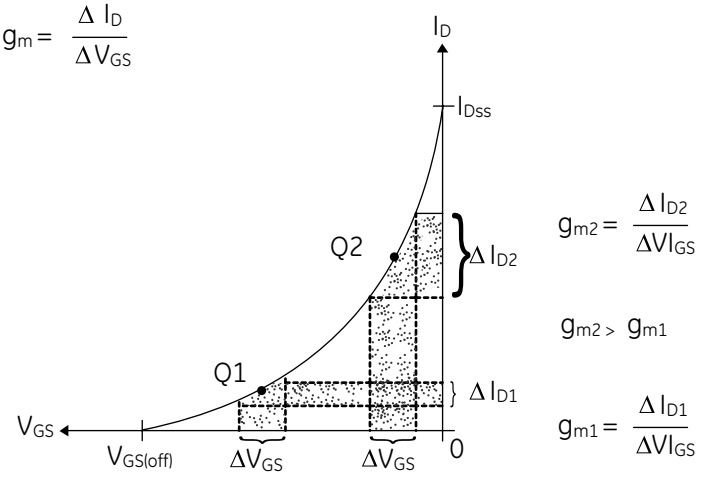
Threshold Voltage [273]

The threshold voltage ($V_{GS(TH)}$) is the minimum value of gate-to-source voltage (V_{GS}) that establishes a channel in an **enhancement mode MOSFET** (E-MOSFET).

Transconductance [266]

Transconductance (gm) is the measurement of a **field effect transistor** (FET) amplifier that is the ratio of a change in drain current to a change in gate-to-source voltage (V_{GS}), measured in microsiemens (μS). It is represented by

$$g_m = \frac{\Delta I_D}{\Delta V_{GS}}$$



Because the characteristic (transconductance) curve for a JFET is nonlinear, gm varies in value, depending on the location on the curve set by V_{GS}. The value for g_m is greater near the top of the curve ($V_{GS} = 0$) than it is near the bottom (near $V_{GS(off)}$). A data sheet usually gives the value of g_m measured at $V_{GS} = 0V$ (g_{mo}). The value of g_{mo} can also be approximated by

$$g_{mo} \approx \frac{-2 I_{DSS}}{V_{GS(off)}}$$

and the value of gm can be approximated at any point on the transconductance curve using the formula

$$g_m \approx g_{mo}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)$$

Transconductance Curve
See **Transconductance**.

Transistor
See **Bipolar Junction Transistor**.

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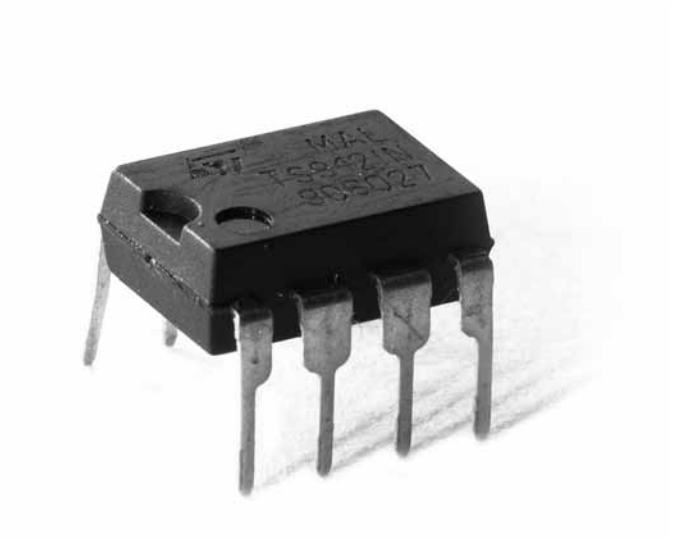
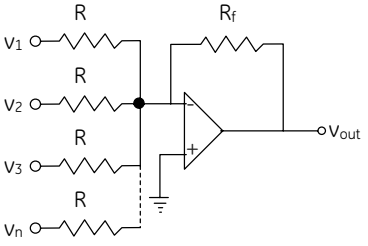
15
Operational Amplifiers



15 – Operational Amplifiers

Averaging Amplifier [265]



Let $\frac{R}{R_f}$ = number of inputs

then

$$v_{out} = -\frac{v_1 + v_2 + v_3 + \ldots + v_n}{\text{number of inputs}}$$

= average of $v_1 \ldots v_n$

Fig 15.1 – Average Amplifier

Closed-Loop Voltage Gain [265]

The closed-loop voltage gain (A_{CL}) is the gain of an op-amp with a feedback path (a signal path from the output to the input). It is always lower than the open-loop gain of the op-amp.

CMRR

See **Common-Mode Rejection Ratio**.

Common-Mode Rejection Ratio [266]

The Common-mode Rejection Ratio (CMRR) is a measure of the op-amp's ability to reject common-mode signals. The CMRR of an op-amp is defined as the open-loop gain (A_{ol}) divided by the common-mode gain (A_{cm}).

$$CMRR = \frac{A_{ol}}{A_{cm}}$$

It is commonly expressed in decibels as:

$$CMRR = 20 \log \frac{A_{ol}}{A_{cm}}$$

Common-Mode Gain [271]

The common-mode gain is the measure of the change in output voltage to a change in voltage applied to both inputs of a differential amplifier.

Comparator [265]

A comparator is a circuit that is used to compare two voltages and to provide an output indicating a relationship between those two voltages. Generally, comparators compare either two changing voltages to each other, or a changing voltage to a set dc reference voltage.

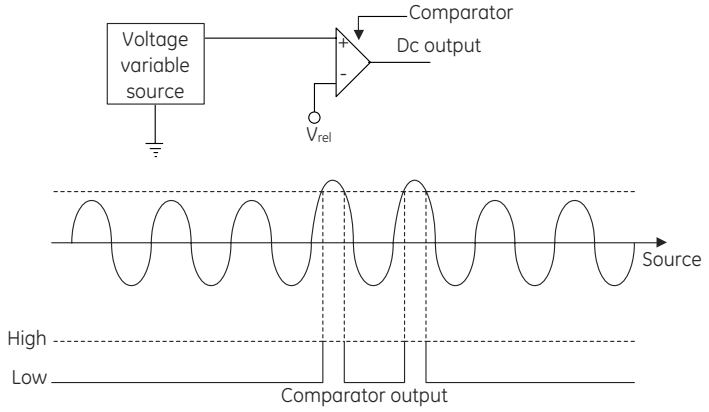


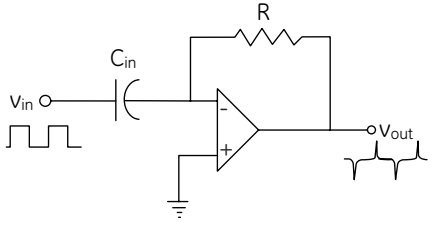
Fig 15.2 – Comparator output

Differential Amplifier [271]

A differential amplifier is an electrical circuit whose output voltage is proportional to the difference between two input signals.

Differentiator [266]

A differentiator is a circuit whose output is proportional to the rate of change of its input signal.

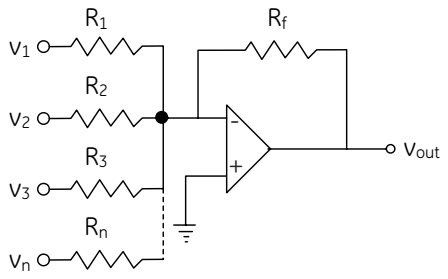


$$\Delta v_{out} = \frac{-v_{in} R C_{in}}{\Delta t}$$

$$v_{out} = -R C_{in} \frac{d}{dt} v_{in}$$

Fig 15.3 - Differentiator

Digital-to-Analog Converter [265]



$$v_{out} = -R_f \left(\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_3}{R_3} + \ldots + \frac{v_n}{R_n} \right)$$

if $R_f = R_1$ and $R_2 = 2R_1$ and $R_3 = 4R_1$ and ...and $R_n = 2^{n-1} R_1$

then

$$v_{out} = -\left(v_1 + \frac{v_2}{2} + \frac{v_3}{4} + \ldots + \frac{v_n}{2^{n-1}} \right)$$

v_1 will be the most significant bit (MSB) and v_n will be the least significant bit (LSB).

Fig 15.4 - Digital-to-Analog Converter

Gain-Bandwidth Product [265]

The gain-bandwidth product of an op-amp is a constant, equal to the **unity gain frequency**. The product of the **closed-loop gain** (A_{CL}) and bandwidth will always approximately equal this constant.

$A_{CL}\, f_2 = f_{unity}$

Input Bias Current [266]

The input bias current is the dc current required by the inputs of the amplifier to properly operate the first stage.

Input Offset Current [266]

The input offset current (I_{OS}) is the difference in the currents of the two input terminals when the output is at zero. Actual magnitudes of offset current is typically 10% or less of the input bias current. The change in offset current with temperature is typically in the range of 0.5 nA/°C.

Input Offset Voltage [266]

The input offset voltage (V_{OS}) is the differential dc voltage required between the inputs to force the differential output to zero volts. Typical values of input offset voltage are in the range of 2 mV or less. In the ideal case, it is 0V.

Input Offset Voltage Drift [266]

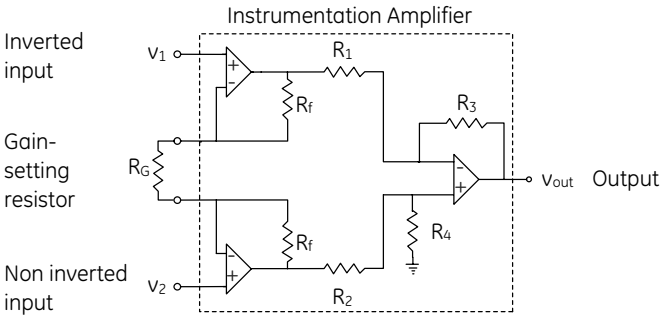
The input offset voltage drift is a parameter that specifies how much change occurs in the **input offset voltage** for each degree change in temperature. Typical values range from about 5 µV/°C to about 50 µV/°C.

Input Voltage Range Rating [265]

The input voltage range rating indicates the maximum voltage the op-amp can handle without risking damage to the internal circuitry.

Instrumentation Amplifier [266]

An instrumentation amplifier consists of three operational amplifiers and several resistors. Integrated circuit manufacturers provide this circuitry on a single chip and package it as one device. Common characteristics are high input impedance (typically 300 MΩ), high voltage gain, and excellent **CMRR** (typically in excess of 100 dB).



If $R_1 = R_2$ and $R_3 = R_4$

$$v_{out} = \left(1 + \frac{2R_f}{R_G}\right)\left(\frac{R_3}{R_1}\right)(v_2 - v_1)$$

if $R_1 = R_2 = R_3 = R_4$

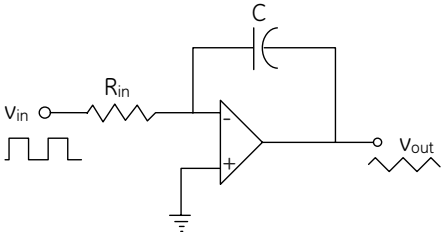
then

$$v_{out} = \left(1 + \frac{2R_f}{R_G}\right)(v_2 - v_1)$$

Fig 15.5 – Instrumentation Amplifier

Integrator [265]

An integrator is a circuit whose output is proportional to the area of the input waveform.

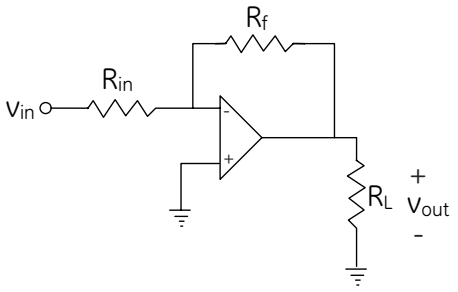


$$\frac{\Delta v_{out}}{\Delta t} = \frac{-v_{in}}{R_{in}C}$$

$$v_{out} = \frac{-1}{R_{in}C}\int v_{in}\,dt$$

Fig 15.6 - Integrator

Inverting Amplifier [265]



$$\alpha_v = \frac{R_{in}}{R_{in} + R_f}$$

$$A_{CL} \approx -\frac{R_f}{R_{in}}$$

$$Z_{in(CL)} \approx R_{in}$$

$$Z_{out(CL)} = \frac{Z_{out}}{1 + \alpha_v A_{OL}}$$

Fig 15.7 - Inverting Amplifier

Inverting Input [265]

The inverting input is the op-amp input that produces an output 180º voltage phase shift.

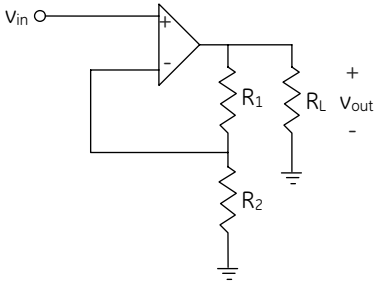
Large Signal Voltage Gain [265]

The large signal voltage gain (A_{OL}) is the open-loop voltage gain for the op-amp.

Level Detector [265]

A level detector is another name for a **comparator** being used to compare an input voltage to a fixed dc reference voltage.

Non-inverting Amplifier [265]



$$\alpha_v = \frac{R_2}{R_1 + R_2}$$

$$A_{CL} = \frac{A_{OL}}{1 + \alpha_v A_{OL}} \approx 1 + \frac{R_f}{R_{in}}$$

$$Z_{in(CL)} = Z_{in}(1 + \alpha_v A_{OL})$$

$$Z_{out(CL)} = \frac{Z_{out}}{1 + \alpha_v A_{OL}}$$

Fig 15.8 - Non-inverting Amplifier

Non-inverting Input [273]

The non-inverting input is the op-amp input that does not produce an output voltage phase shift.

Offset Null [265]

The offset null is a set of inputs on an op-amp that is used to eliminate **output offset voltage**. When power is applied to the circuit, the potentiometer is used to eliminate the output offset.

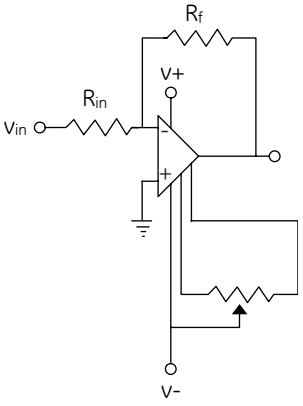


Fig 15.9 – Offset Null

Op Amp

See **Operational Amplifier [265]**.

Op-Amp Identification [265]

Op-amps are identified using a seven-digit character ID code divided into three parts – the prefix, the designator code, and the suffix.

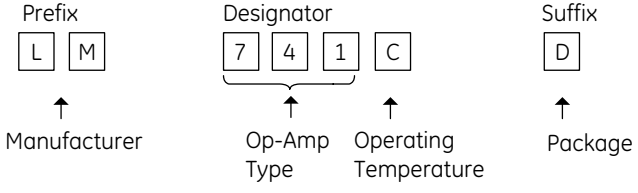


Fig 15.10 - Op-Amp Identification

The prefix is used to identify the particular manufacturer. The designator code is used to designate the op-amp type and the operating range, and the suffix designates the type of package in which the op-amp is housed.

Manufacturers' Prefix

Prefix	Manufacturer
AD	Analog Devices
CA	RCA
LM	National Semiconductor
MC	Motorola
NE/SE	Signetics
OP	Precision Monolithics
RC/RM	Raytheon
SG	Silicon General
TL	Texas Instruments
UA	Fairchild *

Temperature Codes

Code	Application	Temperature Range (°C)
C	Commercial	0 to 70
I	Industrial	-25 to 85
M	Military	-55 to 125

Suffix Codes

Code	Package Type
D	Plastic dual-in-line (DIP)
J	Ceramic DIP
N,P	Plastic DIP with longer lead

* Fairchild is now a division of National Semiconductor.

Table 15.1 - Op-Amp Identification

Op-Amp Packages [265]

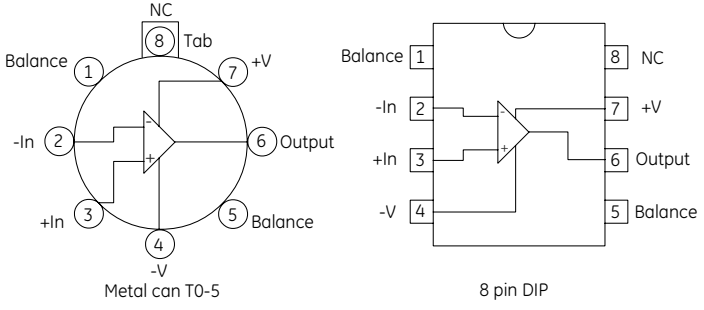


Fig 15.11 - Op-Amp Packages

Op-Amp Parameters [266]

Typical parameters given at 25°C.

Parameter	Op-Amp Type			
	741C	LM101A	LM108	LM218
Input offset voltage	1 mV	1 mV	0.7 mV	2 mV
Input bias current	80 nA	120 nA	0.8 nA	120 nA
Input offset current	20 nA	40 nA	0.05 nA	6 nA
Input impedance	2 MΩ	800 kΩ	70 MΩ	3 MΩ
Output impedance	75Ω	-	-	-
Open-loop gain	200,000	160,000	300,000	200,000
Slew rate	0.5 V/μs	-	-	70 V/μs
CMRR	90 dB	90dB	100 dB	100 dB

Table 15.2 - Op-Amp Parameters

Open-Loop Frequency Response [265]

Op-amps are dc amplifiers (no capacitive coupling exists between stages), and therefore, there is no lower critical frequency. This means that the midrange gain extends down to zero frequency, and the dc voltages are amplified the same as midrange signal frequencies.

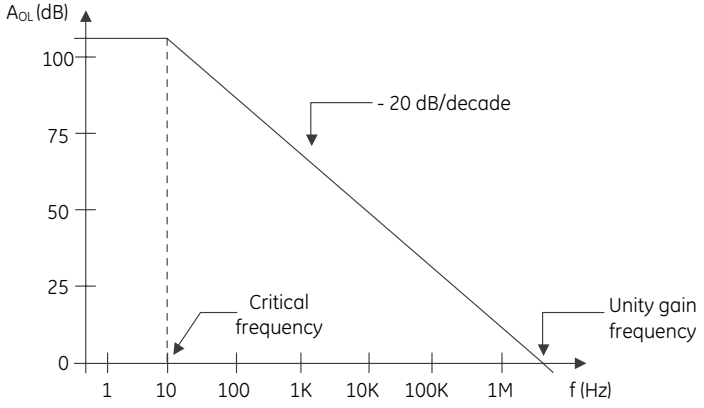


Fig 15.12 - Open-Loop Frequency Response

Open-Loop Voltage Gain [266]

Open-loop voltage gain is the gain of the op-amp without any external feedback from output to input. A good op-amp has a very high open-loop gain; typically, in the range of 50,000 to 200,000.

Operational Amplifier [265]

The operational amplifier (op-amp) is a high gain dc amplifier that has a high input impedance and a low output impedance.

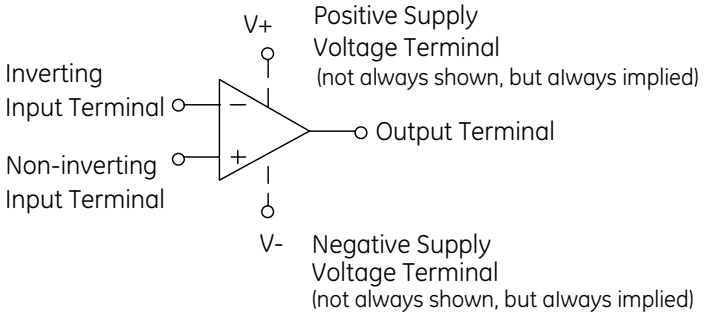


Fig 15.13 - Operational Amplifier

Output Offset Voltage [265]

The output offset voltage is a voltage that may appear at the output of an op-amp, caused by an imbalance in the differential amplifier.

Output Short-Circuit Current Rating [265]

The output short-circuit current rating of an op-amp is the maximum amount of current that will be supplied when the load is shorted.

Power Bandwidth [265]

The power bandwidth is the maximum operating frequency of the op-amp. It can be determined by:

$$f_{max} = \frac{SR}{2\pi V_{pk}}$$

where V is the peak output voltage and SR is the **slew rate**.

Power Consumption Rating [265]

The power consumption rating indicates the amount of power the op-amp will dissipate when it is in its quiescent state.

Power Supply Rejection Ratio Rating [265]

The power supply rejection ratio rating indicates the amount of output from an op-amp will change when the supply voltage changes. Units are in μV/V.

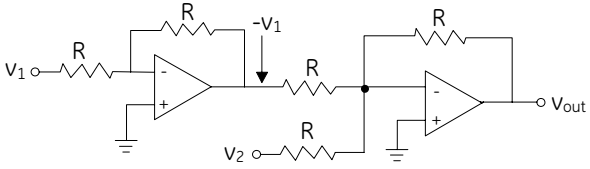
Slew Rate [266]

The slew rate (SR) of an op-amp is the maximum rate of change of the output voltage in response to a step input. It is expressed as:

$$SR = \Delta \frac{V_{out}}{\Delta t}, \text{ with units in V/μs}$$

Subtractor [265]

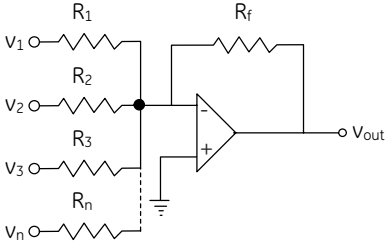
A subtractor circuit is a summing amplifier that provides an output that is proportional to the difference between the input voltages.



$$-V_{out} = V_2 + (-V_1)$$
$$= V_2 - V_1$$

Fig 15.14 - Subtractor

Summing Amplifier [265]



$$V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \ldots + \frac{V_n}{R_n}\right)$$

if $R_1 = R_2 = R_3 = \ldots = R_n = R$
then

$$V_{out} = -\frac{R_f}{R}(V_1 + V_2 + V_3 + \ldots + V_n)$$

Fig 15.15 - Summing Amplifier

Supply Current Rating [265]

The supply current rating of an op-amp indicates the quiescent current that is drawn from the power supply.

Unity-Gain Bandwidth

See **Unity-Gain Frequency**.

Unity-Gain Frequency [266]

The unity-gain frequency is the value of the frequency at which unity gain (0 dB) occurs.

Voltage Follower [265]

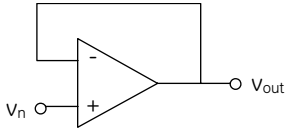
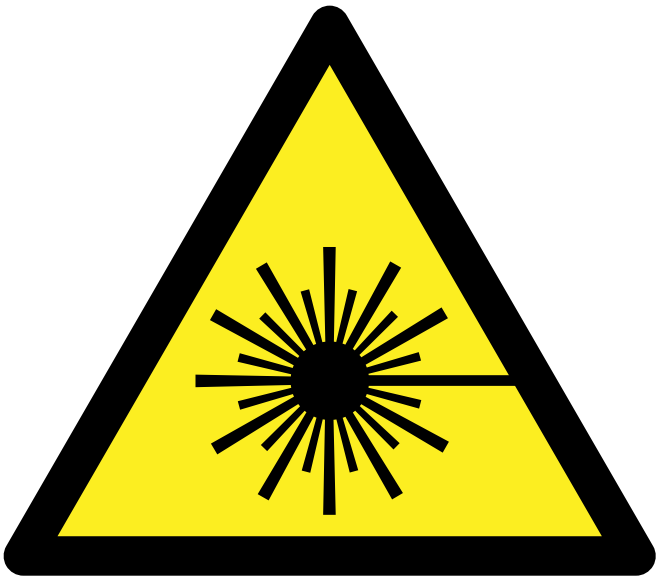


Fig 15.16 - Voltage Follower

$A_{CL} = 1$
$Z_{in} >> Z_{in}$ rating of the op-amp
$Z_{out} < Z_{out}$ rating of the op-amp

16
Lasers



16 – Lasers

Ablation [182]
The removal of tissue by vaporization.

Absorption [182]
Transformation of radiant energy to a different form of energy by interaction with matter.

Absorption (Coefficient) [182]
A factor in determining the ability of light to be absorbed. Different types of tissues have varying properties of absorption.

Accessible Radiation [182]
Optical radiation to which the human eye or skin may be exposed for the condition (operation, maintenance, or service) specified.

Active Medium [182]
The lasing material used to emit the laser light (e.g., argon, carbon dioxide). The laser type is named after the active medium.

Aiming Beam [182]
A guide light often using a HeNe laser or other type of light source for the purpose of directing the primary laser beam to a target.

Airborne Contaminants
Laser generated airborne contaminants (LGACs) is tissue that has been vaporized by the laser beam. Also, see **Plume Control**.

Amplitude [182]
Used in determining power; the maximum peak of a wave. The magnitude of change in the oscillating variable measured from the peak to the valley.

Argon [182]
A gas used as a laser medium, excited in the visible blue-green range (488 and 515 nanometers) of the light spectrum.

Articulated Arm [162]
A delivery device used primarily with CO_2 lasers. The articulated arm is constructed of hollow tubes connected with joints that allow the arm to move. Located in each of the joints are mirrors to reflect the laser beam.

Attenuation [182]
The decrease in the radiant flux as it passes through an absorbing or scattering medium.

Beam Spread
See **Divergence**.

Biostimulation [182]
The use of low power laser or light (milliwatts) to stimulate metabolic activity on a sub-cellular level. Has been under investigational use to relieve pain and promote wound healing.

Carbon Dioxide [182]
A gas used as a laser medium. CO_2 lasers are constructed as a sealed tube or a flowing gas unit and emit energy in the infrared range at 10,600 nm.

Cavity (resonator) [182]
Place where lasing activity occurs between the High Reflective and Output Coupler laser mirrors.

Cautery [182]
Use of laser or electro-surgical units to achieve the hemostasis of tissue or vessels, usually by heat.

Chromophore
A chemical group capable of selective light absorption resulting in the coloration of certain organic compounds.

Classification (Lasers) [186]

ANSI Z136 & IEC 60825 Laser Classification	
Class 1	Incapable of causing injury during normal operation.
Class 1M	Incapable of injury unless collecting optics are used.
Class 2	Visible lasers incapable of causing injury in 0.25 seconds.
Class 2M	Visible lasers incapable of causing injury in 0.25 seconds unless collecting optics are used.
Class 3R*	Marginally unsafe for intrabeam viewing: up to 5 times the class 2 limit for visible lasers or 5 times the class 1 limit for invisible lasers.
Class 3B	Eye hazard for intrabeam viewing.
Class 4	Eye and skin hazard for both direct and scattered exposure.

* Class 3a replaced by 3R

Table 16.1 – Classification of Lasers

Coagulation [182]

The process of congealing, characterized by a transition of material from a liquid to a gelatinous or solid state.

Coherence [182]

Characterized by a fixed phase relationship (spatial coherence) or single wavelength, i.e., monochromatic (temporal coherence).
In laser technology, "coherent light" denotes a light source that produces (emits) light of in-step waves of identical frequency and phase. The laser's beam of coherent light differentiates it from light sources that emit *incoherent* light beams, of random phase varying with time and position; whereas the laser light is a narrow-wavelength monochromatic light.

Collimation [182]

See **Divergence**. Effectively creating a "parallel" beam with very low divergence or convergence.

Combiner Mirror [168]

Allows for the joining of two or more laser wavelength beams into a single coaxial beam (i.e., CO_2 and HeNe beams).

Contact Probe [182]

A probe constructed of synthetic ceramics material (i.e., sapphire). The probe is used with laser fibers, allowing the probe to contact tissue directly, thereby intensifying effects of vaporizing, coagulation, or cutting. This allows for a greater degree of control at relatively low powers.

Continuous Wave (CW) [186]

In the continuous wave (CW) mode of operation, the output of a laser is relatively constant with respect to time. The population inversion required for lasing is continually maintained by a steady pump source. ANSI Z136.1 2007 regards a laser operating with a continuous output for a period equal to or greater than 0.25 seconds as a CW laser.

Controlled Area [186]

Any area that, for the purpose of protection from radiation hazards, is subject to control and supervision.

Dichroic Filter [182]

Dichroic, refers to any optical device which can split a beam of light into two beams with differing wavelengths. Such devices include mirrors and filters, usually treated with optical coatings, which are designed to reflect light over a certain range of wavelengths, and transmit light which is outside that range. Also refers to a material in which light in different polarization states travelling through it experience a varying absorption.

Diffuser [182]

A device or material that causes an even dispersion of light or radiation over a given area. See **Lambertian Surface**.

Diffraction [186]

Is the ability to deviate part of a beam, specific to the radiation wavelength. Diffraction occurs when employing an optical component with a regular pattern, which splits and diffracts light into several beams travelling in different directions. The directions of these beams depend on the

spacing of the grating and the wavelength of the light so that the grating acts as the dispersive element.

Divergence [186]
Divergence, frequently referred to as beam spread, is the increase in diameter of a laser beam with distance from the exit aperture. The divergence of a laser beam is proportional to its wavelength and inversely proportional to the diameter of the beam at its narrowest point.

Dosimetry [182]
A measurement of absorption of energy by tissue. The amount is measured in Joules (watts-sec), and intensity is measured in watts/cm^2.

Energy [186]
The capacity for doing work. Energy content is frequently used to characterize the output from pulsed lasers, and is generally measured in Joules (watt-sec).

Eximer (Excited Dimer) [182]
An excimer laser typically uses a combination of an inert gas (argon, krypton, or xenon) and a reactive gas (fluorine or chlorine). Under the appropriate conditions of electrical stimulation, a pseudo-molecule, called an excimer (or in case of noble gas halides, eciplex) is created, which can only exist in an energized state and can give rise to laser energy in the ultraviolet range.

Excitation [182]
Causing a material to enter a state of population inversion. In physics, the addition of a discrete amount of energy (called excitation energy) to a system—such as an atomic nucleus an atom or a molecule—that results in its alteration, ordinarily from the condition of lowest energy (ground state) to one of higher energy (excited state).

Extended Source (Radiation) [182]
A source of optical radiation that can be resolved by the eye in a geometrical image.

Fail-Safe Interlock [186]
An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

Fiber Optics [182]
The use of glass fibers or flexible quartz as a medium by which laser energy is transmitted. Examples include: communication data, images, and therapeutic laser beams.

Focal Point [182] [136]
A point at which radiation converges or diverges. Described as the distance from an emitting source where the intensity is greatest. In laser application, it is the point where the smallest spot diameter occurs.

Focal Length [186]
A distance measurement from the secondary nodal point of a lens to the primary focal point.

Gated Pulse [182]
A sequenced or timed pulsing of a continuous wave laser light.

Gaussian Curve [182]
A normal statistical curve used to show the cross sectional power distribution in a beam. The curve is used in identifying the geometry of a laser beam, thereby controlling the laser effect.

HCLS
See **Health Care Laser System**.

HCP
See **Health Care Personnel**.

Health Care Laser System (HCLS) [186]
A laser or laser system used for the diagnostic or therapeutic treatment of patients in a health care facility.

Health Care Personnel [186]
An individual directly involved with patient care.

Hemostasis [182]
A term used to identify the stoppage of bleeding.

HeNe [182]
A combination of helium and neon gasses used as a laser medium, produces a visible red wavelength at 630 nm (nanometer); frequently used in aiming beams.

Hologram [182]
A three-dimensional image produced by patterns of interference formed by a split laser beam. These patterns are then illuminated, usually with coherent light.

HpD [182]
A hematoporphyrin derivative used as a cancer treatment drug. This drug is photosensitizing and is used with photodynamic therapy.

Impact Size [182]
The resulting width or depth of an incision created by a laser impact. Impact size is dependent on how energy is applied.

Ionizing Radiation [182]
Any radiation (i.e., X-ray) that has the ability to cause ionization as it moves through a material. Lasers are a non-ionizing radiation.

Infrared Radiation [186]
Electromagnetic radiation, with wavelengths that resides within the range of 0.7µm-1mm, is beyond the visible spectrum of light.

Integrated Radiance [186]
The integral of the radiance over the exposure duration, expressed in units of joules-per-centimeter-squared, per-steradian ($J * cm^{-2} * sr^{-1}$).

Intrabeam Viewing [186]
The condition whereby the naked eye can view all or part of a laser beam.

Irradiance (at a Point of a Surface) [186]
The quotient of the radiant flux incident on an element of the surface containing the point at which irradiance is measured, by the area of that element, expressed in units of watts per square centimeter.

$W * cm^{-2}$

Joule [186]
Measurement of energy. 1 joule = 1 watt * sec.

KTP [182]
A type of crystal (potassium titanyl phosphate) used to "double" the wavelength of an Nd:YAG laser from 1,064nm (infrared) to 532nm (green).

Lambertian Surface [186]
An ideal surface whose emitted or reflective radiance is independent of the viewing angle.

Laser (Light Amplification by Stimulated Emission of Radiation) [186]
Laser is an acronym that stands for Light Amplification by Stimulated Emission of Radiation. High level is a device that emits an intense beam of coherent light.

Laser Medium [182]
Any material used to emit laser light, such as
Solid State – Sapphire, Neodymium (Nd:YAG)
Gas – HeNe, Argon, Carbon Dioxide

Dye – Any dye laser
Diode – Like what is in your DVD player

Laser (Common Types and Applications) [186], [182]

Type	Application	Wavelength
Argon:	Ophthalmology, Photocoagulation (superficial), and Dermatology	488-514 nm, CW
Nd:YAG:	Photocoagulation	1.06 µm (several operating modes)
CO2:	Gynecology, Bronchoscopy General Surgery	10.6 µm, CW
Eximers	Ophthalmology and Cosmetic Surgery (Dermatology) Ultraviolet: Argon fluoride Krypton fluoride Xenon chloride Xenon chloride	 193 nm 248 nm 308 nm 351 nm
Tunable-dye:	Dermatology, Photodynamic Therapy, Cosmetic Surgery	400-900 nm, CW
Gold Vapor:	Photodynamic therapy	628 nm, pulsed
HeNe:	Aiming and Photoradiation	633 nm, CW
Ruby:	Dermatology, Cosmetic Surgery	694 nm, pulsed
Laser diode (GaAs):	Photoradiation, Aiming	840 nm, pulsed

Table 16.2 - Laser (Common Types and Applications)

Limiting Angular Substance (a min) [186]
The apparent visual angle that divides intrabeam viewing from extended-source viewing.

Laser Safety Officer [186]
An authorized individual who has the responsibility to evaluate, monitor, and ensure that proper control of laser hazards are being maintained.

Limiting Aperture [186]
The diameter of a circle over which irradiance or radiant exposure is averaged for purposes of hazard evaluation.

Limiting Exposure [186]
A duration of exposure designed for specific use.

LSO
See **Laser Safety Officer**.

MPE [186]
Maximum permissible exposure = the level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

Metastable State [182]
Occurs when an atom is just below a higher excited state. The higher excited state band that is occupied by an electron momentarily before destabilizing and emitting a photon (light).

Micromanipulator [182]
A delivery device that connects to a microscope to control a laser beam in a microscopic field.

Mode [182]
Used to discern the operating mode of a laser (e.g. pulsed or continuous wave). Also used to describe how the power of a laser beam is distributed within the geometry of a laser beam. See **Transverse Electromagnetic Mode**.

Mode-locking [182]
A process that produces short trains of pulses in the range of 10-20 seconds.

Monochromatic [182]
Waves are all of one (mono) wavelength.

Nanometer (abbev. nm) [186]
Unit of length. 1 nanometer = 10^{-9} meters. Visible light = 400nm to 750 nm.

Neodymium [182]
An active element in Nd:YAG lasers.

Nd:YAG [182]
Neodymium (doped) Yttrium Aluminum Garnet (Nd:YAG) is a

laser medium of mineral crystal. Produces infrared energy at 1,064 nm.

Nominal Hazard Zone (NHZ) [186]
The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE.

Nominal Ocular Hazard Distance (NOHD) [186]
The distance along the axis of the unobstructed beam from the laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure is not expected to exceed the appropriate MPE.

Non-Beam Hazards
Some hazards are deadly!
Electrical: Many lasers utilize extreme high voltages.
Thermal: Lasers can produce extreme tempratures both on beam impact, and internally.
Chemical: Some lasers utilize dyes, solvents, laser gasses and other chemicals, also coolant fluids and cleaning agents.
Mechanical/Ergonomic: Lasers can be physically large, heavy awkward devices. Articulated arms need to have their counterbalance adjusted correctly.
Aerosol: Laser-Generated air contaminants (LGACs). Lasers in use can produce vapors, gasses, dust, fumes and mist ("laser plume") which can carry biologic hazards, aerosolized organic compounds and a multitude of other noxious componants. Hazardous Air Contaminates have only limited MSDS Data.

Nonlinear Effect [182]
The rise in temperature induced by a laser not being of a normal nature.

Optical Density (Dλ or OD) [186]
Logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength.
$D\lambda = - \log_{10} T\lambda$, $1/T\lambda$, where $T\lambda$ is transmittance at the wavelength of interest. OD is the rating label on laser eyewear to identify the level of laser energy they will protect at. An OD of 4 provides more protection then an OD of 2.

Optical Coupler [182]
A mirror that is partially transmissive. Part of the laser cavity that allows a portion (normally 10%) of the laser energy to exit the cavity. This energy is then directed optically to the laser aperture.

Photoablation [186]
The process of ablation with the use of light.

Photodynamic Therapy (PDT) [182]
A procedure using photosensitive drugs which target specific tissues. When exposed to specific wavelengths of laser energy, these drugs are activated to cause selective tissue destruction.

Phase [182]
Wavelengths are considered to be in phase when they align with each other, allowing for highs and lows to match. Should two waves that are exactly in phase meet, the wave is strengthened and in effect now has double the amplitude.

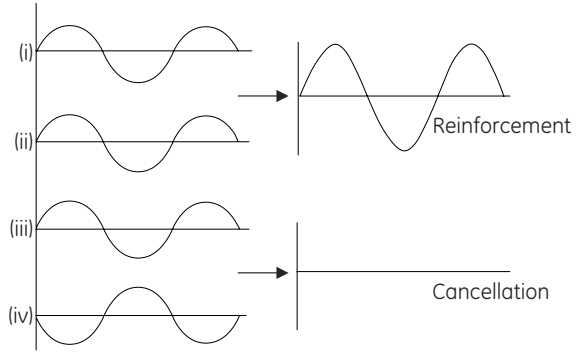


Fig 16.1 – Phase

Waves (i) and (ii) are in phase since all the troughs and all the peaks are apposite each other. The result is a reinforced wave of double the amplitude. Waves (iii) and (iv) are out of

phase since troughs are opposite peaks. The result is a complete cancellation.

Photocoagulation [182]
Coagulation attained with the utilization of light energy (i.e., laser).

Photo Disruption [182]
A cold cutting laser technique whereby an acoustical shock wave is used to snap apart membranes. This process is attained with the Nd:YAG laser, using the Q-switched mode of operation.

Photon [182]
Particle of light.

Photo Radiation
Clinical application that uses a visible wavelength laser, normally a HeNe, to increase activity below the skins surface.

Plasma [182]
A state of matter that has been stripped of a quantity of electrons. As a result, the extremely high temperature expands, creating an acoustical shock wave. Examples of this phenomenon are lightning bolts.

Plasma Shield [182]
The ability of stopping laser light with plasma.

Plume Control [186]
Noxious and potentiality dangerous plumes of smoke are generated as a result of laser energy being used on varying types of tissues. As a result, a smoke evacuator is essential as an effective method of removing these plumes.

Pockel Cell [182]
A component consisting of an electro-optical crystal used to achieve a Q-switch.

Point Source [186]
A radiation source, whose energy level is small enough, due to distance between source and receptor, to be considered negligible in calculations. When viewing star at night, the light from that star is considered a point source.

Population Inversion [182]
A state of excitation where molecules or atoms are excited to a state higher than their lower resting state. This is a prerequisite for lasing action.

Power
Power Is the rate at which energy is expended. It is found by dividing the energy by the time over which it is delivered. The rate of energy delivery is measured in joules/sec. One Joule/sec. equals one watt. Also see **Joules**.

Power Density, (Irradiance) [182]
Expressed in watts per square centimeter, power density is the amount of energy concentrated into a spot of particular size.

PRF [186]
Pulse-repetition frequency. See **Repetitively Pulsed Laser**.

Protective Housing [186]
An enclosure that surrounds the laser system, which limits access to laser radiation above the **MPE** level.

Pulse [182]
Sequential bursts of a laser beam used to achieve higher peak powers than attainable in Continuous Wave (CW) output. Pulses are usually in microseconds or shorter.

Pulse Duration [186]
The duration of a pulse taken between the half-power points of the leading and trailing edge of a pulse.

Pulsed Laser [186]
A laser operating mode that delivers energy in the form of

single pulse or an ongoing chain of pulses. The duration of these pulses are <0.25 sec.

Q-Switching [182]
The ability to switch the laser resonator on and off very quickly producing very high very short peak power bursts. This process is usually achieved using a pockel cell. The bursts described are in nano-seconds.

Radian (Rad) [186]
A unit of angular measurement

1 radian = approx. 57.3 degrees;

2 π radians = 360 degrees.

Radiance [186]
Radiance flux or power output per unit solid angle per unit area in units of watts per centimeter squared per steradian.

$W * cm^{-2} * sr^{-1}$

Radiant Energy [186]
Energy emitted, transferred, or received in the form of radiation. Unit: Joules.

Radiant Exposure [186]
Surface density of the radiant energy received expressed in units of joules per centimeter squared.

$(J * cm^{-2})$

Radiant Flux [186]
Power in the form of radiation, measured in watts either transferred, emitted, or received.

Radiant Power
See **Radiant Flux**.

Reflectance (Reflectivity) [186]
The ratio of total reflected radiant power to total incident power. Also called reflectivity.

Reflected Energy [186]
The use of polished instruments should be avoided due to the potential hazard of reflected laser energy. Anodized instruments are a recommended alternative.

Safety-Interlock
See **Failsafe Interlock**.

Spot-Size [182]
A mathematical measurement of a focused laser spot. Using a **TEM00** beam, it is the area containing 86% of the incident power.

Solid Angle [186]
An angle formed at the vertex of a cone by three or more planes intersecting at a common point. Expressed in steradians (sr).

Specular Reflection [186]
Scattered or reflected energy that is directed from a non-mirrored surface.

Spontaneous Emission [182]
The spontaneous orbital decay of an excited electron from a higher electron band to a lower electron band, creating a photon, without being struck by another photon of light.

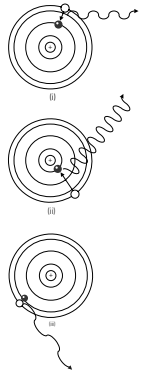


Fig 16.2 - Spontaneous Emission

The diagrams show energized electrons in three atoms decaying back to their original orbits with the spontaneous production of a photon of light. The wavelength and amplitude of the emitted light varies according to the magnitude of the energy change, and is distributed in random directions. The overall light output is incoherent.

Stimulated Emission [184]

The stimulated orbital decay occurs when an excited electron is struck by a photon of light. If an excited electron is struck by a photon of light, it then emits two photons of light of same amplitude and direction as the photon that struck it.

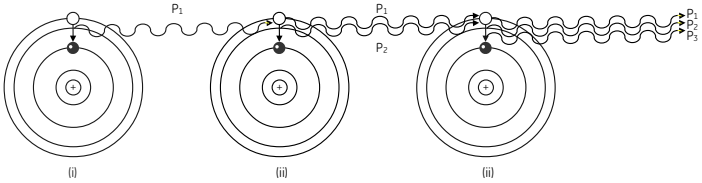


Fig 16.3 - Stimulated Emission

The diagrams show energized electrons in three atoms in a substance that has undergone a population inversion, so that many of the atoms are in an excited state. The first atom (i) undergoes a spontaneous decay and emits a photon P_1. This interacts with a second energized atom (ii), and stimulates the emission of a second photon P_2 with precisely the same wave characteristics, and in perfect phase with P_1. Each of the identical photons can then further stimulate energized atoms to produce additional identical photons, as P_3 etc.

Steradians (sr) [186]

A solid angle unit measurement. There are 4 π steradians about any point in space.

Superpulse [182]

A mode of the CO2 laser whereby the laser output pulses between 250 and 1,000 times per second. Peak power of the pulses is higher than when the laser operates in a continuous wave mode.

Transverse Electromagnetic Mode (TEM) [182]

The technical term for mode. Mode determines the precision of the operative spot size, in the distribution of power over a spot area.

Thermal Relaxation Time [182]

A rate at which a structure can dissipate absorbed energy (heat).

Transmission [186]

Radiation that passes through a medium.

Transmittance [186]

A ratio equal to the total transmitted radiant power to total incident radiant power.

Tunable Dye Laser [182]

A type of laser that incorporates a jet of liquid dye. The dye is pumped (excited) by another laser or flashlamp(s), to produce a variation of wavelengths. Using an optical tuning element, the wavelength of emitted energy may be tuned. 504nm green, 577nm yellow, and 630nm red are used commonly in medical applications.

Ultraviolet Light [186]

Electromagnetic radiation with wavelengths between 0.18 and 0.40 µm, these are shorter wavelengths than those of the visible spectrum.

Visible Radiation (Light) [186]

A term used to describe wavelengths in the range 0.4-0.7 µm. The human eye can detect electromagnetic radiation in this range.

Wavelength [186]

The distance between two consecutive points of a recurrent wave that maintains the same phase.

17
Computer Networks

17 – Computer Networks

10Base2 [196]
10 megabits per second baseband medium, whose maximum segment length is 185 meters (606.8 ft.). It is also known as thin ethernet or cheapernet. Runs on 50 ohm RG-58 a/u coaxial cable with standard center conductor. Cable type Belden 9907 (899907 plenum) or equivalent.

10Base5 [196]
10 megabits per second baseband medium whose maximum segment length is 500 meters (1,640 ft.). It is also known as thick Ethernet. Cable type Belden 9880 (89880 plenum) or equivalent.

10Base F [196]
10 megabits per second medium consisting of fiber optic cables.

10Base T [196]
10 megabits per second baseband medium consisting of unshielded twisted pair cabling whose optimum segment length is 100 meters (328 ft.).

10Broad 36 [194]
10 megabits per second broadband medium whose maximum segment length is 3,600 meters (11,808 ft.).

ABM [120]
Asynchronous Balanced Mode.

ACS [I20]
Asynchronous Communication Server.

ADCCP [120]
Advanced Data Communication Control Procedures (ASAs).

AES [120]
Asynchronous Event Schedule.

AFP [120]
Apple Filing Protocol.

ANSI [120]
American National Standards Institute.

ANW [120]
Advanced Netware.

API (Application Program Interface)
The means by which an applications program talks to communications software. Standard APIs allow application programs to be developed independent of the underlying method of communication.

APPC [196]
Advanced Program to Program Communication (APPC) is an SNA session that provides peer-to-peer communications between network nodes (i.e., PCs, workstations, etc.).

Application [120]
The application layer is the only layer that does not provide any service to another layer. It deals with the user applications and handles communication at a semantics level. The application layer is concerned with problems such as inter-process communication, file transfer, virtual terminal and manipulation services, job transfer, and broadcast communication.

Archie [120]
A system that allows searching of indexes of files that are available on public servers on the Internet.

Architecture [120]
The Architecture, whether a LAN or a computer, is the design structure. In a computer, this structure may be a network

interface card, processor card, interconnecting backplane, disk drivers plane, etc. When discussing the architecture of a LAN, one might be discussing the seven layers that comprise the OSI model.

ARCnet [120]
Attached Resource Computer Network (ARCnet) is an efficient token passing network with a distributed star or unrooted tree topology. ARCnet originated at Datapoint Corporation. The original network offered a 2.5Mbps transmission speed.

ARM [120]
Asynchronous Response Mode.

ARPAnet [118]
Advanced Research Projects Agency Network (ARPAnet) is a packet switching network developed by the Defense Advanced Research Projects Agency (DARPA) to link computing facilities in government agencies and in universities. TCP/IP was originally developed as part of ARPANET

ASCII [120]
American Standard Code for Information Interchange.

ATA [120]
ARCnet Trade Association.

ATM [196]
Asynchronous Transfer Mode (ATM) packages data into cells of 512 bytes for faster effective through put, or data transfer rate.

Backbone Network [118]
A network that links smaller or lower-speed networks, for example, a departmental Ethernet network that connects small workgroup subnets.

Back-Off Period [196]
The time a station waits or backs off from transmitting after it has been involved in a collision. A station is allowed to back off up to 16 consecutive times before it reports an error to the higher layer of protocols.

Baluns [120]
Short for balanced/unbalanced, a balun allows twisted pair cables to be used with Network Interface Cards (NIC) intended for coaxial cable. Baluns provide the heterogeneous link between a coax card and a twisted pair cable on LANs operating at 4 Mbps or slower.

Bandwidth [118]
The range of frequencies that can pass along a cable. The higher the bandwidth, the more 196data that can be transmitted at the same time. Bandwidth is also used more loosely to refer to the data transmission rate itself, or how much data is actually on the network cable at any one point in time.

Baseband [118]
A transmission technique in which only one signal at a time travels along a cable (i.e., no carriers). See **Broadband**.

Baud [122]
When transmitting data, the number of times the medium's state changes per second. For example, a 2400 baud modem changes the signal it sends on the phone line 2400 times per second.

Bulletin Board System (BBS) [196]
A bulletin board system is a single computer system that allows access from multiple remote users via modem connections. Most BBSs offer users varying menu selections that may include software, games, e-mail, and news groups.

Bend Radius [196]
The radius or curvature that a cable, either copper or fiber,

can bend without affecting the signal on the cable.

BIND [122] [196]
Berkeley Internet Name Domain (BIND), the UNIX implementation of DNS, resolving an Internet address to a machine name.

BIOS [120]
Basic Input/Output system.

BIT [196]
A binary digit represented by one of two logic levels, ON or OFF ("1" or "0").

Bits per Second (bps) [122]
The speed at which bits are transmitted over a communication medium.

Bridge [118] [196]
A device that connects two networks. Bridges function at the data link layer of the **OSI model**, and provide protocol-independent forwarding of data between the two networks. Bridges learn on the source address and forwards (or filters) on the destination address. This provides some traffic isolation from network to network. See **repeater, router, and gateway**.

Broadband [118]
A transmission technique in which more than one device can be transmitted at the same time, using different frequencies. Broadband transmission is more complex than baseband, but can achieve higher transmission rates and bandwidth. See **Baseband**.

Broadcast Packet [196]
A packet intended for all devices on the network. A broadcast addressed is placed in the destination address portion of a data packet. The broadcast format is:

FF.FF.FF.FF.FF.FF.HEX

BTW [122]
Common abbreviation in mail and news, meaning by the way.

Bus Topology [118]
A LAN topology in which several devices are attached to a single length of cable running between two points. A bus is also the internal data path connecting a computer's processor with its memory, drives, I/Q devices, and other internal hardware.

Byte [120]
8 bits (nybbles).

Carrier [118]
A signal on a communications medium that does not carry information until changed in some way (e.g., by having its frequency modulated).

CCITT [118]
Comit'e Consultatif Internationale de T'ele'graphique et T'ele' phonique. An international body that develops communication standards (e.g., X.25 and X.400).

CDI [120]
1. Compact Disk Interactive.
2. Cluster Device Interface.

CD ROM [120]
Compact Disk-Read Only Memory.

Cheapernet [118]
A generic name used for Thin Ethernet.

CICS [120]
Customer Information Control System.

CIX [122]
Commercial Internet Exchange (CIX) is an agreement among network providers that allows them to do accounting for

commercial traffic.

Cladding [196]
In a fiber optic cable, it refers to the outer area of glass that encircles the core. The cladding helps direct stray light back into the core due to its lower refractive index with respect to the core. The cladding size is specified in the second number of the fiber size (e.g., 62.5/125 microns). The cladding is 125 micron in diameter.

Client [122]
1. A software application (q.v.) that works on your behalf to extract some service from a server somewhere on the network.
2. A networked computer.

CMIP [118]
Common Management Information Protocol (CMIP), is an OSL network management standard.
See **CMIS**.

CMIS [118]
Common Management Information Services (CMIS) is an OSI network management standard. CMIS services are provided by **CMIP**.

CNE [120]
Certified NetWare Engineer.

Coaxial Cable [118]
Often referred to as coax. A type of cable used in LANS, especially Ethernet. Coaxial cable has a high bandwidth and low susceptibility to electrical interference, however, is relatively expensive and difficult to install.

Collision [196]
The simultaneous transmission of two or more data packets on a cable. The interface of both data packets causes both to be unusable. See **Back-Off Period**.

Connectivity [118]
The ability of devices to transmit data to one another. See **Interoperability**. Devices can have connectivity without necessarily being able to interoperate.

Controller [196]
A device that acts as the electrical and logical interface between a host system and a local area network. In Ethernet, the controller resides in a workstation or file server and is attached to the network cabling by way of transceiver.

CPU [120]
Central Processing Unit.

CRC (Cyclic-Redundancy Check) [196]
An algorithm that generates a particular bit pattern that corresponds to the address and data portions of a packet. The bit pattern is appended to the packet at transmission time. Upon receipt of this packet, the receiving station generates its own CRC bit pattern and compares its results with the CRC bit pattern received with the packet. If the patterns are equal, the packet is considered good.

CSMA [120]
Collision Sense/Multiple Access.

CSMA/CD [118]
Carrier Sense Multiple Access with Collision Detection (CSMA/CD) is a LAN access method in which devices contend for use of the physical medium. If a collision is detected by a transmitting device, it waits and then re-transmits. CSMA/CD is the access method used in Ethernet IEEE 802.3.

CUT [120]
Control Unit Terminal (IBM specific).

DARPA [118]
Defense Advanced Research Projects Agency (DARPA) is a U.S. government agency responsible for ARPANET and the

development of TCP/IP in late 1960s.

Datagram [118]
Data transmitted as an isolated unit across a network. Datagrams, like letters or telegrams, do not have to be delivered in a specific order. In a datagram service error checking (if required) must be carried out by higher-layer protocols or by the user. See **Virtual Circuit**.

Datalink Layer [120]
Layer 2 in the OSI model. The data link layer deals with procedures and services related to the transfer of data from node to node. Its main purpose is to ensure error-free delivery of data packets from a point-to-point network view point.

DCB [120]
Disk Coprocessor Board.

DCE [120]
Data Circuit Terminating Equipment.

DEC [120]
Digital Equipment Corporation.

DDCMP [120]
Digital Data Communications Management Protocol (DEC).

DDNN [122]
Defense Data Network, a portion or the Internet that connects to U.S. military bases and contractors (e.g., MILNET).

DECnet [118]
Digital Equipment Corporation's proprietary network (DECnet) Phase V will be OSI-compliant. See **DNA**.

De Facto Standard [118]
An unofficial standard - one that exists because enough companies adhere to it. See **de jure standard; implementers' agreement**.

De Jure Standard [118]
An unofficial standard - one developed by a standards - making body like IEEE or 1SO. See **de facto standard; implementer's agreement**.

DFS [122]
For all practical purposes, another name for AFS.

DFT [120]
Distributed Function Terminal (IBM specific).

Dial-up [122]
To connect to a computer by calling it up on a telephone; a port (q.v.) that accepts dial-up connections.

DIX [120]
Digital, Intel, Xerox.

DLE [120]
Data Link Escape, 000100 in ASCII.

DMP [120]
Dynamic Memory Pool (as in DMP1, DMP2, DMP3).

DNA [118]
Digital Network Architecture; Digital Equipment Corporation's network architecture. DECnet is an implementation of DNA.

DNS [196]
The Doman Name System (DNS) is a distributed database system for grouping computer names. DNS groups names and addresses to computers so you can log on to any computer in that group and see your normal set of screens.

DOD [122]
The (U.S.) Department of Defense.

DOS [120]
Disk Operating System.

DRAM [120]
Dynamic Random Access Memory.

DSE [120]
Data Switching Equipment.

DTE [120]
Date Terminal Equipment.

EBCDIC [120]
Extended Binary Coded Decimal Information Code.

ECB [120]
Event Control Block.

EIA [120]
Electronic Industries Association.

EISA [120]
Extended Industry Standard Architecture.

E-mail (Electronic Mail) [196]
An effective way to communicate between computers. These computers could reside in the same building, company, or on the other side of the world. Messages can be sent to one individual or to millions by using the network super highway or Internet.

End-to-End [118]
Referring to communication between sources and destination nodes on a network. The transport layer handles end-to-end communication for a node. See **point to point**.

EPROM [120] [196]
Electronically Erasable Programmable Read Only Memory.

E^2PROM or E^2

ESDI [120]
Enhanced Small Device Interface.

Ethernet [118]
A popular local area network. Ethernet is a baseband CSMA/CD network operating in a bus topology at 10 Mbps. The standard version of Ethernet is specified in IEEE 802.3, 10 BASE 5. A broadband version is specified in 10 BROAD 36. A version called **Thin Ethernet** using RG-58 cable is specified in 10 BASE 2, and a version using twisted pair wire is specified in 10BASE T. The fiber optic version is called 10 Base F.

ESR [120]
Event Service Routine.

ETB [120]
End of Transmitted Block (0000100 1110100 in ASCII).

ETR [120]
Early Token Release.

Extended Network [118]
A network that consists of subnets linked together by bridges, routers, or gateways.

FAQ [122]
Frequently asked question(s), or frequently asked questions and answers.

FAT [120]
File Allocation Table.

FCB [120]
File Control Block.

FDDI [118] [196]
Fiber Distributed Data Interface (FDDI) is a 100-Mbps fiber optic network with 2-fiber optic connections to each node, allowing full duplex communication.

FEP [120]
Front End Processor.

Fiber Optic Cable [118]
A transmission medium that uses light waves to transmit data. Fiber optic cable provides higher transmission rates and better security than cable which uses electromagnetic signals, but is more expensive. Fiber optic cable is also impervious to rain, wetness, and lightning.

FIDOnet [196]
A collection of well over 30,000 privately-owned bulletin board systems throughout the world. It allows multiple linking of these BBSs to one another.

File Server [118]
A device on a LAN that provides mass storage of files. See **Workstation**.

FLAME [122] (Editorial Comment)
A virulent and (often) largely personnel attack against the author of a USERNET posting. Flames are unfortunately common.

Frame [118]
In IEEE terminology, the unit of data transferred at the data link layer. It consists of a packet, plus fields containing error-checking and other information. See **Packet**.

Freenet [122]
An organization to provide free Internet access to people in a certain area, usually through public libraries.

FSP [120]
File Service Processes.

FTAM [118]
File Transfer, Access, and Management. An OSI application utility that provides transparent access to files on the network, regardless of the host operating system or file format.

FTP [118]
File Transfer Protocol; TCP/IP application utility.

Gateway [118]
A device that provides protocol translation in linking two networks. A gateway offers the most complete services in connecting networks. See **bridges, repeaters and routers**.

GB [120]
Gigabyte.

GIGO [120]
Garbage In Garbage Out.

GOSIP [118]
Government OSI profile. A federal information process standard that specifies the OST protocols to be required in a U.S. government software contract.

GPI [120]
General Protection Interrupt.

HDLC [120]
High-Level Data-Link Control.

Hub [118]
The central device in a star configured network. See **Concentrator**.

IATA [120]
International Air Transport Association.

IBM Cabling System [118]
IBM's specification for the kinds of cable to be used in connecting its protocol.

IBM LAN Server [118]
A network operating system from IBM, based on LAN Manager.

IBM PC LAN [118]
A LAN from IBM that operates at 2 Mbps using either broadband or baseband transmission. PC Network has proved to be less popular than IBM's Token-Ring Network.

IBM [118] (Token-Ring Network)
A LAN from IBM that uses a token-passing access method in a ring topology. It has versions that run at 4 Mbps and 16 Mbps. The standard is specified in IEEE 802.5.

ICAO [120]
International Civil Air Organization.

IDE [120]
Integrated Drive Electronics.

IEEE [118]
The Institute of Electrical and Electronic Engineers (IEEE) is a society of professional engineers; its 802 member committee develops communication standards.

IETF [118]
Internet Engineering Task Force - An organization responsible for updating and maintaining TCP/IP standards.

IMP [120]
Interface Message Processor (node in Internet network).

Implementer's Agreement [118]
An agreement about the specifics of implementing a standard, reached by vendors who are developing products for the standard. See **de facto standard, de jure standard**.

IMS [120]
Information Management System (IBM specific).

INT [120]
Interrupt; usually refers to software interrupt.

Interoperability [118]
The capacity of devices from different vendors to exchange information and to understand and act upon the information that is exchanged. See **Connectivity**.

Interoperator [118]
A modular piece of hardware or software that implements parts of the OSI model, and can work with hardware or software implementing the other parts of the model.

I/O [120]
Input/Output.

IOCTL [120]
Input/Output Control.

IPX [120]
Internetwork Packet Exchange (IPX), a protocol used by NovelI, derived from Xerox's XNS standard.

IRQ [120]
Interrupt Request Line - usually refers to a hardware interrupt.

ISA [120]
Industry Standard Architecture.

ISAM [120]
Indexed Sequential Access Method (IBM Specific).

ISDN (Integrated Services Digital Network) [196]
An international standard developed by **CCITT**. It is a digital communication channel using the telephone circuit switching or packet switching techniques. ISDN allows 64Kbs per channel, and can be multiplexed with other ISDN bit pipes or channels. It defines a way to package bit streams into packets using the ISDN line like a network connection. Typically, ISDN

access is sold in the following packages:

- Basic Rate includes two 64kbs line and one 16kbs line.
- Primary Rate includes 24 64kbs lines multiplexed into one T1 line.

ISO [118]
The International Standards Organization (ISO) is an organization that promotes the development of open standards for computers and other products. It developed the OSI model for data communication.

Jabber [118]
To transmit continuous random data on a network, due to a malfunction.

K [120]
Kilobyte (1024 bytes)

KB [120]
Kilobyte (1024 bytes).

Kb [120]
Kilobit (1024 bits)

Kbps [118]
Kilobits per second.

LAA [120]
Locally Administered Address.

LAN [118]
Local Area Network. See **Local Area Network**.

LAN Manager [118]
A network operating system developed by Microsoft and 3Com to take advantage of the power features of the OS/2 operating system. Also called OS/2 Manager.

LAN Server [118]
IBM's propriety version of LAN Manager.

LAP [120]
Link Access Protocol.

LAPB [120]
Link Access Protocol Balanced.

Layer [118]
A conceptual level of network processing functions. In the OSI reference model, network processing is thought of as taking place in layers, from the physical transmission of the data up to the issuing of an end-user command.

Layer Interface [118]
The means of communication between protocols operating at adjacent layers in the OSI model. An API is a layer interface, typically functioning at the transport or session layers.

LLC [118]
Logical Link Control (LLC) is the upper sublayer of data link layer, as defined by IEEE 802.2. LLC is common to all IEEE 802 LAN standards, thus allowing higher-layer protocols to operate independent of the actual LAN being used. See **MAC**.

Local Area Network (LAN) [118]
A network that provides a high rate of data transmission and a low error rate in connecting devices over a relatively small area. The local area network is defined in the first two layers of the OSI model. See wide area network.

Local Talk [118]
Apples Computer's proprietary local area network. Apple's network architecture is called AppleTalk, and its network operating system is called AppleShare.

Locking [118]
A procedure that controls access to files so that data is not

destroyed when more than one person tries to change it at the same time.

LSB [120]
Least Significant Bit.

LSL [120]
Link Support Layer.

LU6.2 [118]
See **APPC**.

MAC [118]
Media Access Control. The lower sublayer of the data link layer, as defined by IEEE. There are different MAC protocols for the different IEEE 802 LANs. See **LLC**.

MAN [120]
Metropolitan Area Network.

Manufacturing Message Format Standard [118]
An application-layer protocol developed as part of MAP to provide a syntax for exchanging messages in the manufacturing environment.

MAP/TOP [118]
Manufacturing Automation Protocol/Technical Office Protocol. MAP, originally developed by General Motors, defines OSI protocols and application utilities for use in the same function for the office.

MB [120]
Megabyte, (1,048,576 bytes).

Mb [120]
Megabit, (1,048,576 bits).

Mbps [118]
Megabits per second.

MCA [120]
Microchannel Architecture (IBM specific).

MFM [120]
Modified Frequency Modulation.

MHz [120]
Megahertz.

MHS [120]
Message Handling Service.

MIPS [120]
Millions of Instructions per Second.

MLID [120]
Multiple Link Interface Driver.

mS [120]
Millisecond.

MSB [120]
Most significant Bit

MS-DOS (Microsoft Disk Operating System) [118]
The most popular operating system for PCs. MS-DOS version 3.1 provided networking capabilities for the first time.

MS-NET [118]
A network operating system developed by Microsoft for use with MSDOS version 3.1. Other vendors licensed MS-NET as the basis for their proprietary network operating systems.

MVS [120]
Memory Virtual System (IBM specific).

MVS/XA [120]
Memory Virtual System/Extended Architecture (IBM specific).

Multicast Packet [196]
A packet intended for a specific group of devices. A multicast address is placed in the destination portion of the data packet and is identified by the lowest bit of the first byte odd (e.g., changes from "0" to "1").

Named Pipes [118]
An API for LAN Manager.

NAP [120]
Network Access Protocol.

National Institute of Standards and Technology [118]
A U.S. government agency that develops federal information processing standards for computer acquisitions. Formerly called the National Bureau of Standards.

NetBIOS [118 & 120]
Network Basic Input/Output System (NetBIOS) is an API, originally developed for IBM networks, and now widely used as a standard interface to communications protocols.

NetView [118]
IBM's network management product for its SNA networks. It can collect information from non-SNA environments via NetView/PC.

Netware [118]
A popular proprietary network operating system from Novell Inc.

Network File System [118]
See **NFS**.

Network Layer [118] [196]
Layer 3 in the OSI model, responsible for routing data across the network; ensuring device to device connection.

Network Interface Card (NIC) [120 & 122]
Network Interface Card; also referred to as an NIC. Network Information Center; any organization that's responsible for supplying information about any network.

Network Layer [120]
Layer 3 in the OSI model. The network layer ensures that a packet generated at the source arrives at its destination in a reasonable amount of time. Therefore, this layer handles routing procedures as well as flow control functions.

Network Operating System [118]
Software that manages the resources of a network. Typically, a network operating system provides users with file sharing, electronic mail, a security system, and methods for connecting to other networks.

NFS [122]
Network File System; a set of protocols that allows you to use files on other network machines as if they were local.

NIC
See **Network Interface Card**.

NLM [120]
Netware Loadable Module; a Novell program that supports different kinds of **workstations** or FAX/Print servers (386 based servers).

NOC [122]
Network Operations Center (NOC) is a group that is responsible for the day-to-day care and feeding of a network.

Node [118]
A computer or other device when considered as part of a network.

NOS [118]
Network Operating System.

NSF [120]
National Science Foundation.

NREN [122]
The National Research and Education Network (NREN) is a U.S. effort to combine networks operated by different federal agencies into a single high-speed network.

NSFNET [122]
The National Science Foundation Network (NSFNET) is not the Internet. It's just one of the networks that make up Internet.

Nybble [120]
4 bits (half a byte).

OCTET [122]
Internet standards - monger's language for a set of 8 bits, (i.e., a byte).

ODI [120]
Open Data-Link Interface.

Operating Software Foundation [118]
A consortium of computer companies that is developing a standard version of UNIX.

OS [120]
Operating System.

Open System [118]
A computing system that uses publicly available standards that it can communicate with other systems using the same standards.

Operating System [118]
The software that provides the link between an application program and the physical resources of a computer.

OS/2 [118]
An operating system developed by IBM and Microsoft for PS/2, PC, AT, and compatible computers.

OSI [118] [196]
Open Systems Interconnection. The overall name for ISO's effort to standardize data communication. IS0 has developed a seven-layer model for communication, and is in the process of developing protocols that comply with this model.

7. Application	7, 6, 5 are sets of programs
6. Presentation	that use messages to communicate
5. Session	to another node.
4. Transport	Deals in units of messages
3. Network	Deals in units of packets
2. Data Link	Deals in units of frames
1. Physical	Deals in units of bits

OS/Network Management Forum [118]
A consortium of companies that was formed to support and expedite the development of network management standards.

Packet [118]
The unit of data transmitted at the network layer. Also used generally for a segment of data, along with addressing and other information, that is transmitted on a network. See **Frame**.

Packet-Switching [118]
A data communications technique in which data is segmented into packets, and the packets are sent to their destinations by the fastest route. Individual packets may reach the destination by different routes and in the wrong order. The destination node is responsible for ensuring that packets are reassembled into proper sequence.

PAD [120]
Packet Assembler/Disassembler.

PARC [120]
Palo Alto Research Center.

PC [120]
Personal Computer.

PDU [120]
Protocol Data Unit.

Physical-Layer [120]
Layer I in the OSI model. The physical layer is the most fundamental layer in the OSI model. It is the interface to the physical medium, and provides standards for electrical, mechanical, and functional transmission parameters.

Plenum Cable [120]
A Teflon-jacketed cable used in air handling systems. This cable is often required due to plenum's fire-resistant properties and low smoke-producing qualities, if burned.

Point-To-Point [118]
Referring to communication that takes place between two nodes on a network without passing through any intermediate nodes. The network layer handles point-to-point communication for a node. See **end-to-end**.

Port [122]
A number that identifies a particular Internet application, (e.g., TCP or UDP). One of a computer's physical input/output channels.

POSIX [196]
Portable Operating System Interface for UNIX.

POST [120]
Power On Self Test.

PPP [122]
Point-to-Point Protocol (PPP) is a protocol that allows a computer to use the TCP/IP (Internet) protocols (and become a full-fledged Internet member) with a standard telephone line and a high-speed modem.

Presentation Layer [120]
Layer 6 of the OSI model. The presentation layer deals with the differences in data representation between communicating applications. A syntax is provided by this layer so that any application can understand the content of the piece of information received.

PROM [120]
Programmable Read Only Memory.

Proprietary [120]
Owned or controlled by a single company. A proprietary standard can be used for interoperability if the company that controls it is willing to license it freely or publish its specifications.

Protocol [118]
A set of rules that govern the exchange of information between the same layers in different nodes on a network.

Protocol Stack, Protocol Suite [118]
A set of related protocols. Protocol stack is used when referring to protocols as implementing the layers of the OSI model.

PVC [120]
Poly Vinyl Chloride.

RAM [120]
Random Access Memory.

Redirector [118]
In MS-NET, software that redirects network commands away

from DOS and onto the network.

Repeater [118]
A device that regenerates an electrical signal, thereby increasing the maximum transmission distance of a LAN. See **Bridge, Router, and Gateway**.

RFNM [120]
Ready for Next Message (RFNM), used in **ARPANET**, now **Ethernet**.

Ring [118]
A network topology in which each station is connected in a series to form a closed loop. See **Bus and Star**.

RJ11 or RJ14 [196]
Telephone connectors that can support three pairs of wires.

RJ45 [196]
Telephone connectors that can support four pairs of wires.

RJE [120]
Remote Job Entry.

RLL [120]
Run Length Limited.

ROM [120]
Read-Only Memory.

RPL [120]
Remote Procedure Load (IBM specific).

Router [118]
A device that connects at least two networks. Routers function at the OSI model, and can determine the best route by which to send data. See **Bridge, Gateway, and Repeater**.

RS-232-C [118]
A standard defined by the Electronic Industries Association that specifies a low-speed interface between data communications equipment (like modems) and data terminal equipment (like computers)

RTFM [122]
Common abbreviation in mail and news, meaning read the F ... manual.

SAA [118]
Systems Application Architecture (SAA) is a high-level architecture for IBM products. SAA provides a common programming interface, common means of user access, and common communications support for IBM operating systems.

SAP [120]
Server Advertising Protocol.

SDLC [120]
Synchronous Data-Link Control (IBM specific).

Server [118]
See **File Server**.

Service Provider [122]
An organization that provides connection to a part of the Internet.

Session Layer [120]
Layer 5 in the OSI model. The session layer controls communication between applications. It is responsible for ensuring synchronization so that data exchange is performed in an orderly manner.

SCSI [120]
Small Computer Systems Interface.

SFT [120]
System Fault Tolerant.

Segment Length [196]
Refers to the length of LAN transmission media specified by each network's hardware protocol. In Ethernet implementations, for example, these lengths can range from 600' to 1,640' with coaxial cable as the media, to well over 1.5 miles with fiber optic media. Token ring and ARCnet networks specify other transmission media that have different segment lengths. Usually these protocols also specify the maximum number of nodes per segment.

Shell [118]
In NetWare, it is the software running in the workstation and responsible for directing user commands either to the local operating system or to the network.

Signature [122]
A file, typically five lines or so long, that people often insert at the end of electronic mail messages or **USENET** news articles.

SLIP [122]
Serial Line IP (SLIP) is a protocol that allows a computer to use the Internet protocols (and become a full-fledged Internet member) with a phone and high-speed modem.

SMD [120]
Storage Module Device.

SMFA [118]
Specific Management Function Area (SMEA) is a part of the OSI's network management standards. SMEA will define individual network management services.

SMI [118]
Structure of Management Information (SMI) is a part of OSI's network management standards. SMI will define the basic identification and format of network management data.

SMTP [118]
Simple Mail Transfer Protocol (SMTP) is a TCP/IP application utility.

SNA [118]
Systems Network Architecture. IBM's network architecture for communication among IBM devices and between IBM devices and non-IBM devices.

SNMP [118]
Simple Network Management Protocol (SNMP) is a network management protocol for use with TCP/IP.

Sockets [118]
An application program interface originally developed to link Berkley UNIX to TCP/IP.

SPS [120]
Standby Power System.

SPX [120]
Sequenced Packet Exchange (SPX) (Novell's derivation of Xerox's sequenced packet protocol-SPP), for inter-process communications.

Star [118]
A network topology consisting of a central device (often called a hub) that has other devices linked to it. All communication between devices takes place via the hub. In a more complex configuration. hubs are also linked, forming a hierarchical topology. See **Bus and Ring**.

StarLAN [118]
A baseband CSMA/CD local area network operating in a star or daisy chain topology at 1 Mbps. StarLAN was originally developed by AT&T, and is now part of the IEEE 802.3 standard.

Station [118]
A device connected to a network.

STREAMS [118]
UNIX V.3s's framework for network communications.

Subnet [118]
A network that is part of a larger extended network. Subnets can be linked to the extended network via bridges, routers, or gateways.

Systems Network Architecture (SNA) [118]
A digital communications facility developed by AT&T that transmits data at 1.544 Mbps.

SWIFT [120]
Society for Worldwide Interbank Financial Transactions.

Switched Access [122]
A network connection that can be created and destroyed as needed. Dial-up connections are the simplest form of switched connections.

T1 [196]
A digital grade telephone line that can carry up to 24 Time Divisions Multiplexed (TDM) voice lines. These multiplexed lines can support 64Kbps of digital data each, for a combined bandwidth of 1.544 Mbps. Developed by AT&R in 1962.

T3 [196]
One T3 line can multiplex up to 28 T1 lines, for a combined bandwidth of 44.54Mbps.

TCAM [120]
Telecommunication Access Method (IBM specific).

TCP [122]
The Transmission Control Protocol (TCP) is one of the protocols on which the Internet is based.

TCP/IP [118]
Transmission Control Protocol/Internet Protocol (TCP/IP) is the name applied to a popular protocol suite developed by the Defense Advanced Research Projects Agency (DARPA). TCP is the transport-layer protocol in this suite, and IP is the network-layer protocol.

TDR [120]
Time Domain Reflectometer.

Telnet [118]
A TCP/IP application utility that provides terminal emulation. (not to be confused with Telenet, a public packet-switching network.)

Terminal Emulation Program [118]
Software that allows a PC to act like a dumb computer terminal. Terminal emulation lets a PC communicate with a mainframe or minicomputer, at the expense of the PC's processing power.

Terminal Service [118]
A terminal server lets users of terminals connect to more than one computer.

Thin Ethernet
See **10base2**.

Time Out [122]
A time out is what happens when two computers are talking and one computer, for any reason, fails to respond. The other computer will keep on trying for a certain amount of time, but will eventually give up.

TIP [120]
Terminal Interface Processor (node w/no host in Internet).

TP [120]
Twisted Pair.

3+ [118]
A popular network operating system from 3Com Corp.

TLI [118]
Transport Layer Interface (TLI) is an application program interface provided with UNIX System V Release 3.

tn3270 [122]
A special version of the telenet program that interacts properly with IBM mainframes.

Token [118]
A unique combination of bits that travels around the network in the token-passing access method. See **Token Passing**.

Token Bus [118]
A LAN that uses the token-passing access method with a bus topology. IEEE 802.4 is the standard for a token bus network. MAP specifies token bus as the LAN portion of its protocol stack.

Token-Passing [118]
An access method in which a token is passed around the network, and is made available to each station on the network. Only the station that has the token can transmit on the network. See **CSMA/CD**.

Token Ring [118]
A LAN that uses the token-passing access method with a ring topology. IEEE 802.5 is the standard for a token-ring network.

Topology [118]
The physical layout of a network. The principle LAN topologies are bus, ring, and star.

TP4 [118]
OSI's connection-oriented transport-layer protocol.

Transceiver [118]
A device that both transmits and receives. In Ethernet technology, a transceiver provides the electrical and physical interface to the network cable, monitoring the cable for activity, and detecting collisions. It is also called a media access unit.

Transport Layer [120]
Layer 4 in the OSI model. The transport layer is the lowest among the layers that only provide services locally for an end user. It ensures that the lower three layers are providing adequate services for application communication, as far as the transmission medium and the information flow are concerned. The transport layer creates a logical transparent pipe between end users.

TRN [120]
See **Token Ring Network**.

TSR [120]
Terminal and Stay Resident.

TTS [120]
Transaction Tracking System.

Twisted Pair Wire [118]
Cabling that consists of individual wires wrapped around each other. Twisted pair wire is commonly used for telephone connections, and is becoming popular as a LAN medium.

UDLC [120]
Universal Data Link Control (from Sperry).

UDP [122]
The User Datagram Protocol; another protocol on which the Internet is based, and part of the TCP/IP suit.

ULTRIX [118]
Digital Equipment Corporation's version of UNIX.

UNIX [118]
A popular multiuser, multitasking operating system developed by AT&T. There are currently many different versions, and several, different efforts to create a standard.

UNMA [118]
Unified Network Management Architecture - AT&T's proprietary architecture for network management.

UPS [120]
Uninterruptable Power Supply.

USENET [122]
The USENET is an informal, rather anarchic, group of systems that exchange news.

UUCP [122]
UNIX-to-UNIX copy - a facility for copying files between UNIX systems, on which mail and USENET news services were built.

UTP [120]
Unshielded Twisted Pair.

VADD [120]
Value-added Disk Driver.

VAP [196]
Value-added Process (VAP), like NLM, but for 286 based servers. See **NLM**.

VAR [120]
Value-added Reseller.

VAX [120]
Virtual Address Extension (DEC).

VINES [118]
Virtual Networking System. A network operating system from Banyan System, Inc.

Virtual Circuit [118]
A communications link that gives the user the impression that there is a dedicated communication channel between the local and remote device. The impression is created by processing that ensures delivery of the data in the order in which it was sent. See **Datagram**.

Virtual Terminal [118]
An OSI applications utility that provides remote terminal emulation.

VLS [120]
Very-Large-Scale Integration.

VMS [120]
Virtual Memory System.

VTAM [120]
Virtual Terminal Access Method (IBM specific).

WAN
See **Wide Area Network**.

WAIS [122]
Wide-area Information Servers (WAIS) is a very powerful system for looking up information in databases across the Internet.

Wide Area Network [118]
A communications network that covers a large area (hundreds or thousands of miles) by using lines provided by a common carrier, such as the telephone company. See **Local Area Network**.

Workgroup [118]
The basic networking unit within an organization, consisting usually of fewer than a dozen users with an ongoing need to share information and peripheral devices.

Workstation [118]
A device, typically a PC, from which a user communicates with a file server or other central computer.

World-Wide Web [122]
A hypertext-based system for finding and accessing Internet resources.

WWW [122]
See **World-Wide Web**.

WORM [120]
Write Once. Read Many times (type of optical disk).

WSTN [120]
Workstation.

X.25 [118]
A CCITT standard that defines a protocol for gaining access to public packet-switching networks. See Packet-Switching.

X.400 [118]
A CCITT standard far electronic mail, included in OSI, as an application utility.

XENIX [118]
A version of UNIX that runs on IBM PC ATs.

XNS [118]
Xerox Network Systems (XNS) is a network architecture for LANs developed by XEROX Corporation. Although generally considered superior to TCP/IP for LAN, XNS never became as popular as a communication standard; proprietary derivatives, however, are in widespread use.

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18
Conversion Tables

18 – Conversion Tables

Conversion Factors

Multiply	By	To obtain
acres	0.4047 43,560.0 1.5625×10^{-3}	hectares square feet square miles
ampere hours	3600.0	coulombs
angstrom units	3.937×10^{-9} 1×10^{-4}	inches microns
astronomical units	1.496×10^{8}	kilometers
atmospheres	76.0	centimeters of mercury
atomic mass unit	9.316×10^{8} 1.492×10^{-10} 1.66×10^{-27}	electron-volts joules kilograms
BeV (also GeV)	10^{9}	electron-volts
BTU	3.93×10^{-4} 778.3 2.93×10 1.0×10^{-5}	horsepower-hours foot-pounds kilowatt hours therms
BTU/hr	0.2161 3.929×10^{-4} 0.293	foot-pounds/sec horsepower watts
bushels	2150.4	cubic inches
calories, gram (mean)	3.9683×10^{-3}	BTU (mean)
centares	1.0	square meters
centimeters	1×10^{-5} 1×10^{-2} 10.0 3.281×10^{-2} 0.3937	kilometers meters millimeters feet inches
chains	792.0	inches
coulombs	1.036×10^{-5}	faradays
cubic centimeters	0.06102 2.113×10^{-3}	cubic inches pints (U.S. liquid)
cubic feet	0.02832 7.4805	cubic meters gallons
cubic feet/min	62.43	pounds H_2O/min
cubic feet/sec	448.831 0.064632	gallons/min millions of gallons per day
cubits	18.0	inches
days	86,400.0	seconds
degrees (angle)	1.745×10^{-2}	radians
degrees/sec	0.1667	revolutions/min
dynes	1×10^{-3}	newtons
electron volts	1.074×10^{-9} 10^{-9} 1.602×10^{-19} 1.783×10^{-36} 10^{-6}	atomic mass units BeV (also GeV) joules kilograms MeV
faradays/sec	96.500	ampercs (absolute)
fathoms	6.0	feet
feet	30.48 0.3048 1.645×10^{-4} 1.894×10^{-4}	centimeters meters miles (nautical) miles (statute)
feet/min	0.05080	centimeters/sec
feet/sec	0.592 0.6818	knots miles/hour
foot-pounds	1.285×10^{-3} 5.051×10^{-7} 3.766×10^{-7}	BTU horsepower-hr kilowatt-hours
foot-pound/sec	4.6272 1.818×10^{-3} 1.356×10^{-3}	BTU/hr horsepower kilowatts
furlongs	660.0 0.125	feet miles (U.S.)
gallons	0.1337 3.785	cubic feet liters
gallons H_2O	8.3453	pounds H_2O
gallons/min	8.0208 0.002228	cubic feet/hr cubic feet/sec
GeV (also BeV)	10^{9}	electron-volts
grams	10^{-3} 3.527×10^{-2} 3.215×10^{-2} 2.205×10^{-3}	kilograms ounces (avoirdupois) ounces (troy) pounds
hectares	2.471 1.076×10^{5}	acres square feet
horsepower	2545.0 42.44 550 0.07457 745.7	BTU/hr BTU/min foot-pounds/sec kilowatts watts
horsepower-hour	2545.0 1.976×10^{6} 0.7457	BTU foot-pounds kilowatt hours

Multiply	By	To obtain
hours	4.167×10^{-2} 5.952×10^{-3}	days weeks
inches	2.540 1.578×10^{-5}	centimeters miles
inches, H_2O	5.199 0.0361 0.0735	lbf/ft^2 psi inches, mercury
inches, mercury	70.7 0.491 13.60	lbf/ft2 psi inches, H2O
joules	6.705×10^{9} 9.480×10^{-4} 1×10^{7} 6.242×10^{18} 1.113×10^{-17}	atomic mass units BTU ergs electron-volts kilograms
kilograms	6.025×10^{26} 5.610×10^{35} 8.987×10^{16} 2.205	atomic mass units electron-volts joules pounds
kilometers	3281.0 1000.0 0.6214	feet meters miles
kilometers/hr	0.5396	knots
kilowatts	3412.9 737.6 1.341	BTU/hr foot-pound/sec horsepower
kilowatt-hours	3413.0	BTU
knots	6076.0 1.0 1.151	feet/hr nautical miles/hr statute miles/hr
light years	5.9×10^{12}	miles
links (surveyor)	7.92	inches
liters	1000.0 61.02 0.2642 1000.0 2.113	cubic centimeters cubic inches gallons (U.S. liquid) milliliters pints
MeV	10^{6}	electron-volts
meters	100.0 3.281 1×10^{-3} 5.396×10^{-4} 6.214×10^{-4} 1000.0	centimeters feet kilometers miles (nautical) miles (statute) millimeters
microns	1×10^{-6}	meters

Multiply	By	To obtain
miles (nautical)	6076 1.853 1.1516	feet kilometers miles (statute)
miles (statute)	5280.0 1.609 0.8684	feet kilometers miles (nautical)
miles/hr	88.0	feet/min
milligrams/liter	1.0	parts/million
milliliters	1×10^{-3}	liters
millimeters	3.937×10^{-2}	inches
newtons	1×10^{5}	dynes
ohms (international)	1.0005	ohms (absolute)
ounces	28.349527 6.25×10^{-2}	grams pounds
ounces (troy)	1.09714	ounces (avoirdupois)
parsecs	3.086×10^{13} 1.9×10^{13}	kilometers miles
pascal-sec	1000 10 0.02089 0.6720 0.02089	centipoise poise pound force-sec/ft^2 pound mass/ft-sec slug/ft-sec
pints (liquid)	473.2 28.87 0.125 0.5	cubic centimeters cubic inches gallons quarts (liquid)
poise	0.002089	pound-sec/ft^2
pounds	0.4536 16.0 14.5833 1.21528	kilograms ounces ounces (troy) pounds (troy)
pounds/ft^2	0.006944	pounds/in^2
pounds/in^2	2.308 27.7 2.037 144	feet, H_2O inches, H_2O inches, mercury pounds/ft^2
quarts (dry)	67.20	cubic inches
quarts (liquid)	57.75 0.25 0.9463	cubic inches gallons liters
radians	57.30 3438.0	degrees minutes
revolutions	360.0	degrees
revolutions/min	6.0	degrees/sec

Multiply	By	To obtain
rods	16.5 5.029	feet meters
rods (surveyor)	5.5	yards
seconds	1.667×10^{-2}	minutes
square meters/sec	10^6 10.76 10^4	centistokes square feet/sec stokes
slugs	32.174	pounds
stokes	0.0010764	square feet/sec
tons (long)	1016.0 2240.0 1.120	kilograms pounds tons (short)
tons (short)	907.1848 2000.0 0.89287	kilograms pounds tons (long)
volts (absolute)	3.336×10^{-3}	starvolts
watts	3.4129 1.341×10^{-3}	BTU/hr horsepower
yards	0.9144 4.934×10^{-4} 5.682×10^{-4}	meters miles (nautical) miles (statute)

Common SI Unit Conversion Factors

Area

Multiply	By	To obtain
circular mil	506.7	square micrometer
square feet	0.0929	square meter
square kilometer	0.3861	square mile
square meter	10.764 1.196	square feet square yard
square micrometer	0.001974	circular mil
square mile	2.590	square kilometer
square yard	0.8361	square meter

Energy

Multiply	By	To obtain
BTU (international)	1.0551	kilojoule
erg	0.1	microjoule
foot-pound	1.3558	joule
horsepower-hour	2.6485	megajoule
joule	0.7376 0.010197	foot-pound meter-kilogram force
kilogram-calorie (international)	4.1868	kilojoule
kilojoule	0.9478 0.2388	BTU kilogram-calorie
kilowatt hour	3.6	megajoule
megajoule	0.3725 0.2278 0.009478	horsepower-hour kilowatt-hour therm
meter-kilogram force	9.8067	joule
microjoule	10.0	erg
therm	105.506	megajoule

FORCE

Multiply	By	To obtain
dyne	10.0	micronewton
kilogram force	9.8067	newton
kip	4448.2	newton
micronewton	0.1	dyne
newton	0.10197 0.0002248 3.597 0.2248	kilogram force kip ounce force pound force
ounce force	0.2780	newton
pound force	4.4482	newton

HEAT

Multiply	By	To obtain
BTU/ft^2-hr	3.1546	watt/m^2
BTU/ft^2-°F	5.6783	watt/m^2-°C
BTU/ft^3	0.0373	megajoule/m^3
BTU/ft^3-°F	0.06707	megajoule/m^3-°C
BTU/hr	0.2931	watt
BTU/lbm	2326	joule/kg
BTU/lbm-°F	4186.8	joule/kg.°C
BTU/-inch/ft^2-hr-°F	0.1442	watt/meter.°C

joule/kg	0.000430	BTU/lbm
joule/kg-°C	0.0002388	BTU/lbm-°F
megajoule/m^3	26.839	BTU/ft^3
megajoule/m^3.°C	14.911	BTU/ft^3-°F
watt	3.4121	BTU/hr
watt/m.°C	6.933	BTU-inch/ft^2-hr-°F
watt/m^2	0.3170	BTU/ft^2-hr
watt/m^2.°C	0.1761	BTU/ft^2-hr

LENGTH

Multiply	By	To obtain
Angstorm	0.1	nanometer
foot	0.3048	meter
inch	25.4	millimeter
kilometer	0.6214 0.540	mile mile (international nautical)
meter	3.2808 1.0936	foot yard
micrometer	1.0	micron
micron	1.0	micrometer
mil	0.0254	millimeter
mile	1.6093	kilometer
mile (international nautical)	1.852	kilometer
millimeter	0.0394 39.370	inch mil
nanometer	10.0	Angstorm
yard	0.9144	meter

MASS (weight)

Multiply	By	To obtain
grain	64.799	milligram
gram	0.0353 0.03215	ounce (avoirdupois) ounce (troy)
kilogram	2.2046 0.068522 0.0009842 0.001102	pounds-mass slug ton (long-2240 lbm) ton (short-2000 lbm)
milligram	0.0154	grain
ounce (avoirdupois)	28.350	gram
ounce (troy)	31.1035	gram
pounds-mass	0.4536	kilogram
slug	14.5939	kilogram
ton (long-2240 lbm)	1016.047	kilogram
ton (short-2000 lbm)	907.185	kilogram

PRESSURE

Multiply	By	To obtain
bar	100.0	kilopascal
Inch, H_2O (20°C)	0.2486	kilopascal
Inch, Hg (20°C)	3.3741	kilopascal
kilogram force/cm^2	98.067	kilopascal
kilopascal	0.01 4.0219 0.2964 0.0102 7.528 0.1450 0.009869 7.5006	bar inch, H_2O (20°C) inch, Hg (20°C) kilogram force/cm^2 millimeter Hg (20°C) psi standard atmosphere (760 torr) torr
millimeter Hg (20°C)	0.13284	kilopascal
psi	6.8948	kilopascal
standard atmosphere (760 torr)	101.325	kilopascal
torr	0.13332	kilopascal

POWER

Multiply	By	To obtain
BTU (international)/hr	0.2931	watt
foot-pound/sec	1.3558	watt
horsepower	0.7457	kilowatt
kilowatt	1.341 0.2843	horsepower tons of refrigeration
meter-kilogram force/second	9.8067	watt
tons of refrigeration	3.517	kilowatt
watt	3.4122 0.7376 0.10197	BTU (international)/hr foot-pound/sec meter-kilogram force/second

TEMPERATURE

Multiply	By	To obtain
Celsius	9/5(°C+32)	Fahrenheit
Fahrenheit	5/9(°F-32)	Celcius
Kelvin	9/5	Rankine
Rankine	5/9	Kelvin

TORQUE

Multiply	By	To obtain
gram force centimeter	0.098067	millinewton-meter
kilogram force meter	9.8067	newton-meter
millinewton	10.197	gram force centimeter
newton-meter	0.10197 0.7376 8.8495	kilogram force meter foot pound inch pound
foot-pound	1.3558	newton-meter
inch-pound	0.1130	newton-meter

VELOCITY

Multiply	By	To obtain
feet/sec	0.3048	meters/second
kilometers/hr	0.6214	miles/hr
meters/second	3.2808 2.2369	feet/sec miles/hr
milers/hr	1.60934 0.44704	kilometers/hr meters/second

VISCOSITY

Multiply	By	To obtain
centipoise	1.0	millipascal-seconds
centistoke	1.0	micrometer^2/seconds
millipascal-second	1.0	centipoise
micrometer^2/second	1.0	centistoke

VOLUME (Capacity)

Multiply	By	To obtain
cubic centimeter	0.06102	cubic inch
cubic foot	28.3168	liter
cubic inch	16.3871	cubic centimeter
cubic meter	1.308	cubic yard
cubic yard	0.7646	cubic meter
gallon (U.S.)	3.785	liter
liter	0.2642 2.113 1.0567 0.03531	gallon (U.S.) pint (U.S. fluid) quart (U.S. fluid) cubic foot
milliliter	0.0338	ounce (U.S. fluid)
ounce (U.S. fluid)	29.574	milliliter
pint (U.S. fluid)	0.4732	liter
quart (U.S. fluid)	0.9464	liter

VOLUME FLOW (gas-air)

Multiply	By	To obtain
cubic meter/sec	2119	standard cubic foot/min
liter/sec	2.119	standard cubic foot/min
microliter/sec	0.000127	standard cubic foot/hr
milliliter/sec	0.002119 0.127133	standard cubic foot/min standard cubic foot/hr
standard cubic foot/min	0.0004719 0.4719 471.947	cubic meter/sec liter/sec milliliter/sec
standard cubic foot/hr	7866 7.8658	microliter/sec milliliter/sec

VOLUME FLOW (liquid)

Multiply	By	To obtain
gallon/hr (U.S.)	0.001052	liter/sec
gallon/min (U.S.)	0.06309	liter/sec
liter/sec	951.02 15.850	gallon/hr (U.S.) gallon/min (U.S.)

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Biomedical Resource Agencies

19 – Biomedical Resource Agencies

Agency for Health Care Policy and Research
6000 Executive Blvd., Suite 309
Rockville, MD 20852
(301) 594-4023

American Association of Blood Banks
8101 Glenbrook Rd
Bethesda, MD 20814-2749
Phone (301) 907-6977
Fax (301) 907-6895
www.aabb.org

American Hospital Association (AHA)
One North Franklin
Chicago, ILL. 60606-3421
Phone (312) 422-3000
www.aha.org

American Public Health Association
800 I Street, NW
Washington, DC 20001
Phone (202) 777-2742
Fax (202) 777-2534
www.apha.org

American National Standards Institute (ANSI)
1819 L Street, NW (6th floor)
Washington, DC 20036
Phone (202) 293-8020
Fax (202) 293-9287
www.ansi.org

American Society for Healthcare Engineering (ASHE)
One North Franklin 28th Floor
Chicago, IL 60606
Phone (312) 422-3800
Fax (312) 422-4571
www.ashe.org

Association for the Advancement of Medical Instrumentation (AAMI)
1110 North Glebe Road, Suite 220
Arlington, VA 22201-4795
Phone (800) 332-2264 ext. 210
(703) 276-0793
www.aami.org

Canadian Standards Association International (CSA)
8501 East Pleasant Valley Road
Cleveland, Ohio, USA, 44131-5575
Tel: (216) 524-4990
Fax: (216) 642-3463
www.csa-international.org

Center for Disease Control and Prevention (CDCP)
1600 Clifton Rd NE
Atlanta, GA 30333
Phone 800-CDC-INFO (800-232-4636)
www.cdc.gov

College of American Pathologists (CAP)
325 Waukegan Road
Northfield, IL 60093-2750
Phone 800-323-4040
Fax 847-832-8000
www.cap.org

Department of Health and Human Services (DHHS)
200 Independence Ave SW
Washington, DC 20201
Phone (877) 696-6775
www.hhs.gov

Digital Imaging and Communications in Medicine (DICOM)
NEMA, Suite 1752
1300 North 17th Street
Rosslyn. VA 22209
Phone (703) 841-3285
www.dicom.nema.org
www.medical.nema.org

ECRI
5200 Butler Pk
Plymouth Meeting, PA 19462
(610) 825-6000
www.ecri.org

Health Industry Manufacturers Association (HIMA)
1200 G St NW Suite 400
Washington, DC 20005
(202) 783-8700

Institute of Electrical and Electronics Engineers (IEEE)
2001 L Street, NW. Suite 700
Washington, DC 20036-4910 USA
Phone (202) 785-0017
Fax (202) 785-0835
www.ieee.org

International Certification Commission for
Clinical Engineering and Biomedical Technology
1110 N. Glebe Road, Suite 220
Arlington, VA 22201- 4795
Phone (703) 525-4890, ext. 207
Fax (703) 276-0793
www.aami.org/certification

International Organization for Standardization (ISO)
1, ch. de la Voie-Creuse,
Case postale 56
CH-1211 Geneva 20, Switzerland
Phone 41 22 749 01 11
Fax 41 22 733 34 30
www.iso.org

Joint Commission on Accreditation of Healthcare
Organizations (JCAHO)
One Renaissance Blvd
Oakbrook Terrace, IL 60181
(630) 792-5800
www.jointcommission.org

Laser Institute of America
13501 Ingenuity Drive, Suite 128
Orlando, FL 32826
Phone (800) 345-2737
Fax (407) 380-5588
www.laserinstitute.org

National Fire Protection Association (NFPA)
1 Batterymarch Pk
Quincy, MA 02269-9101
(617) 770-3000
www.nfpa.org

National Institute for Occupational Safety and Health (NIOSH)
(See **CDC**)
1-800-CDC-INFO (1-800-232-4636)
www.cdc.gov/niosh

Occupational Safety & Health Administration (OSHA)
200 Constitution Avenue, NW
Washington, DC 20210
Phone (800)-321-6742
www.osha.gov

The American Institute of Architects (AIA)
1735 New York Ave., NW
Washington, DC 20006-5292
Phone (800) AIA-3837
Fax (202) 626-7547
www.aia.org

Underwriters Laboratory Inc. (UL)
2600 N.W. Lake Rd.
Camas, WA 98607-8542
Phone (877) 854-3577
Fax (360) 817-6278
www.ul.com

U.S. Department of Health and Human Services
Public Health Service
Food and Drug Administration
Center for Devices and Radiological Health
200 Independence Avenue, S.W.
Washington, D.C. 20201
Phone (877) 696-6775
www.hhs.gov

U.S. Food and Drug Administration
10903 New Hampshire Ave.
Silver Spring, MD 20993
Phone (888) 463-6332
www.fda.gov

U.S. Nuclear Regulatory Commission (NRC)
Washington, DC 20555-0001
Phone (800) 368-5642
www.nrc.gov

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